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Internal Controls, Collusion, and Hierarchical Structure

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Internal Controls, Collusion, and Hierarchical Structure

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To my parents

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This study uses the principal–agent framework to investigate the trade-off between the benefits of internal control stemming from a reduction of the losses from inappropriate employee actions and the costs of implementing it brought about by the possibility of collusion that it creates. It is shown that, when the agents find it relatively easy to collude, implementing internal control reduces agency welfare, defined as the sum of expected payments accruing to the principal and the agents, even as, with positive transaction costs of collusion, it improves productive efficiency, defined as the expected output. As a result, the principal, under certain conditions, finds it in her best interest to use internal control as a threat instead of implementing it. When this is the case, the principal sometimes prefers to decrease the accuracy of the accounting information system. The analysis of the agents' side contracting indicates that, even if the principal can prevent explicit collusion, for some values of parameters the possibility of tacit collusion still results in a loss. The study also investigates the effect of the choice of organizational form on the value of internal control. The analysis of two different versions of the model demonstrates that, for a wide range of parameters, creating a hierarchical structure reduces, albeit does not eliminate, the loss from collusion — i.e., internal control and hierarchical delegation are complementary instruments of organizational design. It is also shown that, when one agent is *ex ante* more likely to be efficient than the other, in most cases the principal optimally appoints to the supervisory position the one who is *less* likely to be efficient. As a result, the supervisor, in expectation, exerts a lower effort level than the subordinate and collects higher salary.

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Chapter 1

Introduction

Internal control is a valuable tool of corporate governance that has long been used by companies to reduce the losses from employee fraud and improve productivity by minimizing the occurrence of both intentional and unintentional errors. The recent series of corporate scandals, of which Enron and WorldCom are but two prominent examples, and especially the ensuing legislation that included the Sarbanes-Oxley Act of 2002 (SOX), have rekindled the interest in internal control, on the part of both practitioners and researchers, as a means of restoring investors' trust in financial markets. The purpose of this study is to extend the literature documenting the practice of internal control by using the tools from the managerial economics toolbox to study two important properties: (i) the effect of internal control on the welfare of both shareholders and employees and (ii) the effect of the organizational structure on the value of internal control to the shareholders.

From the viewpoint of managerial economics — and, more specifically, the principal–agent framework — internal control is a mechanism that helps reduce the losses stemming from information asymmetries between principals and agents. For the most part, the literature on internal control in organizations (and control in general) has focused on identifying and quantifying the benefits that it brings about, the costs involved in implementing it, and the best practices of increasing the former and reducing the latter. Since internal control is often considered primarily as an instrument of preventing employee malfeasance (although a broader view of internal control as an integral part of enterprise risk management has been advocated of late: see, e.g., COSO, 2004), the benefits often reflect the reduction of the loss from fraud. Various efficiency improvements, including the positive effect on financial reporting, are also considered among the benefits. The costs of internal control reflect, among other things, the waste of time required to get decisions approved, reduced motivation when employees construe the presence of control as lack of trust (see, e.g., Falk and Kosfeld, 2006), or actions taken by the controlled parties with a view to circumventing it.

In Chapter 2, I focus on the latter category of costs and show that, even when internal control itself does not involve any unproductive waste of resources, the attempts to circumvent it by the employees reduce efficiency when the employees being controlled find it relatively easy to collude. That is, when collusion is easy, the principal (representing the board, which acts on behalf of the shareholders) finds it in her best interest to use internal control as a threat instead of actually implementing it.[1] The intuition behind the result is that, in response to internal control, the agents (representing employees) take actions so as to minimize their loss — and these actions affect not just their reporting strategies but their productive outputs as well. The mechanism captured by the model is similar in spirit to the well-known effect of financial reporting requirements on the economic decisions of the reporting entity, where the managers manipulate not just the reported figures but the underlying economic transactions as well. The vulnerability of internal control to collusion has long been pointed out by both practitioners and accounting researchers (see, e.g., Carmichael, 1970, and Kinney, 2000a): in fact, implementing internal control virtually always creates the possibility of collusion between (or among) the employees involved in it. To the best of my knowledge, however, the investigation of the effect of internal control and collusion that it brings about on productive and allocative efficiency presented in Chapter 2 is new.

To investigate the mechanism through which collusion reduces the value of internal control, I consider, in Chapter 3, the benchmark setting where communication between the agents is impossible and show that, for a wide range of parameters, the principal can attain the first-best allocation — i.e., eliminate the loss from explicit

[1]Throughout the dissertation, I use feminine gender to refer to principals and masculine gender to refer to agents.

collusion altogether. Nonetheless, in many circumstances the possibility of *tacit* collusion, where the agents do not coordinate their actions but still take improper advantage of the information asymmetry, remains. The analysis of the benchmark case demonstrates that the most effective way of improving the value of internal control involves disrupting the agents' negotiations over their collusive agreement, or side contract. Several avenues toward this end have been proposed in the literature: see, e.g., Beck (1986) and the references in Chapter 2. In real-life settings, however, the principal will have at best a limited influence on the informal dealings among the employees. On the other hand, she will usually have access to another instrument that has a bearing on how easy it is for the agents to collude: the choice of the organizational form. I explore this possibility in Chapter 4.

Internal controls observed in practice often involve employees occupying different rungs of the hierarchical ladder. A textbook example (see McWatters, Morse, and Zimmerman, 2001, p. 182) involves a lower-level employee responsible for initiating a transaction and the supervisor ratifying it. The cases where it is the subordinate who, in effect, controls the boss by, e.g., being a co-signatory on financial documents, are also well-known. In Chapter 4, I investigate the effect of the organizational form chosen by the principal on the value of internal control. The analysis of two different organizational arrangements demonstrates that in many circumstances internal control is, indeed, more valuable in a hierarchical setting — even though by creating it and delegating to the supervisor contracting with the lower-level agent, the principal loses some flexibility in contracting with the latter. The main result reported in Chapter 4 is that, for a wide range of parameters, internal control and hierarchical structure (i.e., delegation) are complementary instruments. That is, even in the absence of technological reasons to create a hierarchical structure, putting one in place is often justified because it increases the value of internal control. I also show that, when one of the agents is more likely to be efficient (in the sense to be defined presently) than the other, the principal usually appoints to the supervisory position the one who is *less* likely to be efficient because an efficient supervisor collects a higher information rent than an efficient subordinate.

The results reported in this dissertation further our understanding of internal control as an instrument of corporate governance and, more specifically, of the mechanisms through which the choice of the organizational form determines its value. The analysis shows, in particular, that in most cases eliminating collusion altogether is infeasible, unless the principal can "sell" the business to the supervisor — but the benefits from internal control exceed the losses from collusion. The model also highlights the important difference between internal control and control in general, which has been investigated by organizational researchers for more than a century. The latter can be thought of as involving a continuous and direct interaction between the controller (the principal) and the controlled (the agent), while in the former the continuous interaction typically takes place between the supervisor and the agent — i.e., "below the radar" of the principal, who intervenes only when the internal control system signals the presence of a problem. The advantages of internal control can then be explained in terms of reduction of the burden of information processing carried out by the principal.

Since reviewing the voluminous literature on internal control in its entirety is beyond the scope of this dissertation, I only quote the sources that are directly related to the modeling approach adopted here. For a thorough review of the accounting literature on internal control the reader is referred to Jones (1996). It should be noted, however, that the topic in question is quite broad and straddles several academic disciplines including law, management science, and industrial organization, among others. For example, Lewis and Sappington (1997) and Khalil, Kim, and Shin (2006) investigate the benefits of separating planning and implementation, which is a classic example of the segregation of duties, the most-often used internal controls. A comprehensive review of the literature containing a synthesis of different approaches adopted by various disciplines has yet to be written.

Chapter 2

Internal Controls and Efficiency

Recent years have seen renewed interest in internal control as a means of improving corporate governance in publicly traded companies.[1] This interest is, at least in part, fueled by complaints about the burdens imposed on companies by Section 404 of SOX that requires managers to report on, and external auditors to attest to, the adequacy of internal controls over financial reporting. The discussion, which goes on in both the popular and academic press, has centered on the comparison of benefits and costs of internal control. For example, Committee on Capital Markets Regulation (2006, p. 115) states:

> The key issue is not the statute's underlying objectives but whether the implementation approach taken by the SEC and the PCAOB (the independent board established under SOX to set standards for auditors of public companies) strikes the right cost-benefit balance. There is widespread concern that the compliance costs of Section 404 are excessive.

The participants in the discussion — especially regulators and practitioners — appear to agree that internal control brings about significant benefits (e.g., in reducing

[1]Some authors use the terms *internal control* and *corporate governance* interchangeably. For example, Berkovitch and Israel (1996, p. 210) give the following defintion: "External control refers to the market for corporate control where managers are replaced and disciplined via takeovers. Internal control refers to arrangements within the firm, like the control of the board of directors over the management team and contractual agreements such as bond covenants." In this study, I use the term in its strict (accounting) sense, which will be made precise presently.

the cost of capital: see Lambert, Leuz, and Verrecchia, 2007, and Ashbaugh-Skaife, Collins, Kinney, and LaFond, 2006) and focus on quantifying these benefits and comparing them with costs, which fall into two broad categories: (i) the costs of implementing and operating internal control and (ii) the costs of reporting on, and auditing, its effectiveness. Examples of the former include resources expended on verification, ratification, approval, and similar activities; examples of the latter — auditors' fees directly related to auditing internal controls. *Compliance costs* typically contain elements of both.

Even though the accurate measurement of these costs remains a challenging task, their nature is relatively well understood. Yet, as noted by Power (1997), there is still much confusion in practice about what effective internal controls really are. In a similar vein, Kinney (2000b) argues that the effect of internal control on the welfare of management, corporate directors, shareholders, trading partners, auditors, and society at large remains, to a large degree, unexplored by researchers. Kinney's observation is echoed by Maijoor (2000) who also remarks that internal controls should be studied from a corporate governance perspective. To explicate the costs and benefits that may, in a cross-sectional empirical study, be obscured by the above-mentioned compliance costs, I present a model where internal control is costless to implement and study its effects on productivity and payoffs accruing to (productive) agents and shareholders.

Internal controls comprise a wide array of policies and procedures ranging from very traditional, such as installing locks in warehouses, to very innovative, such as monitoring employees' computer use in real time (Allison, 2006). As diverse as they are, however, all known internal controls share one common shortcoming: they are susceptible to organizational corruption, which is also often referred to as collusion.[2] An internal control mechanism may be used for nefarious purposes, such as abuse of authority, or simply "overridden" by the persons entrusted with implementing it as a result of collusion (Kinney, 2000a). I leave the former problem for future research and, in this paper, investigate the latter.

To make the task manageable, I focus on one type of internal control: the often-used practice of segregation (or separation) of duties, where a business is organized

[2]The latter term is most often used in the economics literature and has a more precise meaning than the former. I will use both terms interchangeably.

in such a way that no single person could carry out any process or transaction in its entirety. In this type of internal control, the actions of one individual affect the payoff(s) of his colleague(s). I study a stylized model of a company composed of a principal, representing shareholders or top management acting on their behalf, and two agents, representing individual workers or division managers. The agents engage in productive tasks that may be interdependent, in the sense that one agent's productive effort affects the output of his colleague. The principal can use this *productive interdependency*, in combination with a sufficiently accurate accounting information system, as an internal control mechanism that makes it more difficult for the agents to shirk (i.e., collect information rents).

Productive interdependency is pervasive in organizations. For example, it is virtually always present when individuals are organized in teams: in fact, it often serves as the main reason to put the agents on a team so that shirking by one member creates negative externalities for everyone. Productive interdependency also occurs in other settings. Consider a factory where a purchasing manager may be bribed by a supplier to accept components of inferior quality. Even though the agreement between the manager and the supplier is not observable, the combination of unfavorable direct-material quantity and direct-labor efficiency variances in the manufacturing department (owing to additional scrap and rework) will point to the likely cause of the problem. In a similar fashion, the actions of the production manager will have a bearing on the outputs of his colleagues in other departments. In this example, a technological link between the purchasing and manufacturing departments provides information about the actions of both managers and thus acts as a natural internal control.

In many cases, the degree of productive interdependency can be varied within a certain range. In the example above, the principal who wishes to alter the extent to which the output of the production manager depends on the effort of the purchasing manager can do so by, say, investing in a quality control system to conduct incoming inspection of components entering the manufacturing department. In other cases, the properties of available technology will not allow the principal to eliminate technological interdependency completely. And, in settings where no natural interdependency exists, it may be introduced on purpose, which is precisely the point of segregation of duties.

The purpose of internal control is to reduce the negative consequences of information asymmetry between the principal and the agents. From the standpoint of consumers, the problem created by information asymmetry is that the expected level of output (or, equivalently, productive effort) that is produced when the principal hires the agents is lower than the the first-best level of output that obtains under symmetric information. *Productive efficiency*, defined as the expected level of the agents' productive effort, provides a measure of how close the outputs attainable under various organizational arrangements are to the first-best, or socially optimal, level. In this chapter I show that, in the absence of implementation and reporting costs, (1) when collusion between the agents is relatively easy, internal control that increases productive efficiency decreases agency welfare, defined as the sum of the principal's and the agents' payoffs; (2) when this is the case, the principal, under certain conditions, prefers to use internal control as a threat instead of implementing it; and (3) lowering the accuracy of the accounting information system may increase the principal's expected payoff.

The first result is brought about by the principal's choice of productive efforts required of the agents, which involves a trade-off between inefficiently low effort levels and information rents. When the agents find it relatively easy to collude, the effort levels required of them are such that agency welfare is lower with internal control than without, i.e., the agents' loss from internal control exceeds the principal's gain. In other words, *not* implementing internal control creates a surplus, which, under certain conditions, can be shared by the agents and the principal; hence the second result. I will call the loss in agency welfare from implementing internal control a *structural* cost, to distinguish it from implementation and reporting costs.

One would expect that the threat of collusion can diminish, and potentially eliminate, the benefit from internal control. The model, however, demonstrates that, when the principal is required (e.g., by SOX) to implement internal control, collusion can actually cause her to sustain a *loss* relative to the benchmark case with no internal control — even though internal control itself is costless and improves productive efficiency. This result helps explain loud complaints by executives about high compliance costs associated with internal control: anecdotal evidence suggests that many companies that were required to implement internal control by regulations (e.g., the Foreign Corrupt Practices Act of 1977) preceding SOX had simply not done so and now must incur both reporting *and* implementation costs. The model also predicts that the principal may prefer to sever technological links that already exist, thus providing an additional explanation for decisions to decentralize by granting company divisions high levels of autonomy or spinning them off.

The third result is brought about by the crucial role of the accounting information system in implementing internal control. If the principal is better off using it only as a threat (and not implementing it) but available technology does not allow her to eliminate productive interdependency completely, under certain conditions she benefits from reducing the accuracy of the information system.

The Committee of Sponsoring Organizations of the Treadway Commission (COSO) gives the following definition of internal control:

> Internal control is broadly defined as a process, effected by an entity's board of directors, management and other personnel, designed to provide reasonable assurance regarding the achievement of objectives in the following categories:
>
> - Effectiveness and efficiency of operations.
> - Reliability of financial reporting.
> - Compliance with applicable laws and regulations.[3]

The model developed in the paper can be interpreted either in terms of the first type, often referred to as operational internal controls, or the second, also known as controls over financial reporting. Indeed, productive units that are modeled in this study can represent both individual employees and separate divisions that report their financial results to the central office because, in this setting, the scale of production is irrelevant. Although SOX and, to a large extent, the current discourse on corporate governance have primarily focused on internal controls over financial reporting, both types appear to be important — and are, to a great degree, interlinked. For this reason, the term "internal control" is used here to denote both. I leave the explication of internal controls over compliance for future research.

[3]See COSO (1994, p. 13).

2.1 Related Literature

The central trade-off in the model is between the benefits of internal control, which makes it more difficult for the agents to shirk, and potential losses from collusion that internal control induces. Organizational collusion has been studied extensively in formal economic models. Tirole (1986, 1992) and Laffont and Tirole (1991) investigate a three-tier principal–supervisor–agent hierarchy where collusion takes the form of an agreement between the supervisor and the agent to conceal information about the agent's type that is valuable to the principal. These authors show that, absent contracting frictions (such as restrictions on contract types or costly communication), collusion, both actual and potential, is harmful to the principal. For the most part, the subsequent literature has followed the Laffont–Tirole tradition and focused on settings where a supervising agent, who may or may not exert productive or monitoring effort, observes some information about a productive agent and may be paid by the latter to distort (usually, conceal) this information. The general results are that a threat of collusion may reduce, but does not eliminate, the benefits of supervision (Kofman and Lawarrée, 1993) and that a better supervision technology increases welfare (Laffont, 2001, Proposition 2.3).

In the presence of contracting frictions, however, these results may no longer hold. For example, in Laffont and Meleu (1997) two productive agents engage in mutual monitoring and can enter a side-contract (i.e., collusive agreement) with non-linear transaction costs. This property of their side-contract, in effect, imposes a restriction on the set of admissible contracts available to the principal, who may, as a result, find that increasing the quality of monitoring reduces her payoff. In Khalil and Lawarrée (2006) the principal's inability to commit to conducting a costly *ex post* investigation may render the supervision by a collusive monitor useless.

Several studies demonstrate that, in some settings, collusion can actually have a beneficial effect. Olsen and Torsvik (1998) show that the principal can benefit from collusion between the supervisor and the agent because it alleviates the problem of limited commitment. Chen (2003) demonstrates that collusion may be beneficial for the principal because it introduces an incentive for the agents to communicate their private information. In his model, the restriction on the type of admissible contracts takes the form of sequential contracting: the principal has to make an investment decision before she contracts with the agent, whose private information is pertinent to the decision. In Lawarrée and Shin (2005), the principal benefits when she enriches the agents' action space by allowing them to choose their productive tasks and thus make a better use of their private information, even though by so doing she, in effect, restricts her own action space.[4] Papers demonstrating, in the hidden information framework, that collusion may have beneficial effects when the principal's action or information space is restricted also include Che (1995), Strausz (1997), and Shin (2006).

The focus in this chapter, however, is not on collusion *per se* but on internal control, with collusion emerging as byproduct of implementing the latter as the agents' attempt to minimize its effect on their information rents. One of the two potential benefits of internal control is that, with it in place, an agent cannot shirk unilaterally: in order to collect his information rent he now has to collude with his colleague. Collusion always reduces the agents' expected information rent relative to the benchmark case with no internal control and, in that sense, is beneficial to the principal. But collusion also brings about the shortcoming of internal control. In the models mentioned above the agent's decision with respect to his effort is separable from his decision to collude with the supervisor. In contrast, in this chapter, when internal control is implemented, the agent's decision with respect to effort level is *inseparable* from his decision to collude. As a result, the principal's response to the threat of collusion involves requiring the agents to exert effort levels that reduce agency welfare relative to the benchmark case.

Internal control provides a second benefit to the principal. Without it, she has to know the types of both agents if she wants to extract their information rents. In the presence of internal control she only has to know the type of one agent: she can then deduce the type of his colleague by observing the output levels. If transfers between the agents entail transaction costs, the principal can take advantage of this useful property by choosing one agent and paying him the amount that is (weakly) greater than what he can gain by colluding with the colleague.

The desirability of merging what otherwise would be independent operations to make one agent's compensation a function of the actions of his colleague was first

[4] Itoh (1993) obtains a similar result in a moral hazard setting.

pointed out, in a different setting, by Demski and Sappington (1984), who propose a direct revelation mechanism that is useful to the principal but is costly to operate. Ma, Moore, and Turnbull (1988) show that the principal can do better by offering the agents an indirect mechanism that gives one of the agents a choice of additional output levels: by choosing one of these levels, the agent communicates information about his colleague to the principal (or, in other words, turns his colleague in). The mechanism is further refined by Glover (1994) who demonstrates that, by offering just one additional output level that can be used to communicate private information, the principal can approximate the second-best solution.

The desirability, from the principal's standpoint, of implementing internal control is thus a function of the magnitude of the above-mentioned cost and benefits, as well as the principal's ability to share with the agents the surplus that obtains when internal control is not implemented and the costs of collusion are relatively low. Under certain conditions that are often observed in practice, such as sequential contracting with the agents, the principal is, indeed able to extract the surplus and as a result obtains a higher expected payoff when internal control is not implemented than when it is. It should be noted here that, unlike the two benefits, the loss in agency welfare is discontinuous at zero. In that sense, it behaves very much like a fixed cost: the principal incurs it the moment she "switches on" internal control. As its intensity increases, so does the benefit from reducing the agents' information rent, until the benefit is just equal to the cost. Only when the intensity of internal control is above this "break-even" value is the principal's payoff increased when she implements it.

The chapter proceeds as follows. The model is introduced in Section 2.2. In Section 2.3, I solve the model and characterize the principal's decision to implement internal control. Her choice of the accounting information system is discussed in Section 2.4; Section 2.5 concludes.

2.2 The Model

Consider a firm composed of three risk-neutral parties: a principal and two agents, labeled A and B. The principal owns the firm but does not possess the requisite expertise to operate it, while the agents are capable of operating the firm but lack financial resources to buy it from the principal. I assume that the principal cannot assign one of the agents to perform both tasks. Agent i exerts effort $e^i \geqslant 0$ at a cost $c(e^i) = \frac{1}{2}\left(e^i\right)^2$, $i = A, B$. Agents' efforts determine outputs produced by their respective divisions according to the following production function:[5]

$$\begin{cases} x^A(e^A, e^B) = \theta^A + (1-\alpha)\, e^A + \alpha e^B, \\ x^B(e^A, e^B) = \theta^B + \alpha e^A + (1-\alpha)\, e^B, \end{cases} \tag{2.1}$$

where θ^i is the efficiency parameter that characterizes the "fit" between agent i and the division that he operates and is not known to him *ex ante*. For example, when an executive from Boeing Co. is appointed as the CEO of Ford Motor Co., his past success at the former company does not guarantee adequate performance at the latter. Parameters θ^i can take one of two values, θ_l and θ_h, with $\Delta\theta = \theta_h - \theta_l > 0$. It is common knowledge that, with probability ν (resp., $1-\nu$), agent i is efficient (resp., inefficient) in the sense that his productivity parameter θ^i is equal to θ_h (resp., θ_l). I assume that $0 < \nu < 1$. Agent i's effort and efficiency parameter are his private information.

Only the agents observe the output given by (2.1); the principal observes a verifiable report, $\mathbf{r}(\mathbf{x}) \in \mathbb{R}^2$, generated by the company's accounting system.[6] For simplicity, assume that the report function $r\colon \mathbb{R}^2_+ \mapsto \mathbb{R}^2_+$ admits the following representation: $\mathbf{r}(\mathbf{x}) = \left(r^A(x^A),\, r^B(x^B)\right)$. The accuracy of the accounting system is characterized by the (scalar) margin of error of the report function, $m(r)$, which is defined as follows:

$$m(r) \equiv \max_{\mathbf{x}\in\mathcal{X}} \| \mathbf{x} - \mathbf{r}(\mathbf{x}) \|,$$

where $\mathcal{X} \subset \mathbb{R}^2_+$ is the set of all possible realizations of output $\mathbf{x}$. In most of the

[5] This can be seen as a special case of a more general production function given by

$$x^A(e^A, e^B) = \theta^A + \alpha_{11} e^A + \alpha_{12} e^B,$$
$$x^B(e^A, e^B) = \theta^B + \alpha_{21} e^A + \alpha_{22} e^B.$$

Setting $\alpha_{11} = \alpha_{22}$ and $\alpha_{12} = \alpha_{21}$ simplifies the exposition considerably without changing the qualitative nature of the results. The normalization $\alpha_{11} = 1 - \alpha_{21} \equiv 1 - \alpha$ is adopted to facilitate comparisons across various regimes. Very similar results obtain with three agents.

[6] I will occasionally denote the two-dimensional output by $\mathbf{x} = \left(x^A, x^B\right)$, using boldface letters to represent (row) vectors.

chapter I assume that the principal has at her disposal an accounting system characterized by a perfect reporting function (i.e., the one with $m(r) = 0$); the case of a positive margin of error is considered in Section 2.4.

Production function (2.1) can be interpreted as a stylized model of segregation of duties, where the principal's goal is to make sure that no process or transaction is carried out by a single agent. The principal attains this goal by setting $\alpha > 0$. The above formulation also captures the effect of positive externalities that often exist across divisions and firms. For example, high-quality blueprints produced by a design engineer make the production engineer's job easier, and a qualified production engineer may be able to spot the designer's errors and expedite the process of correcting them. It is likely that in real-life situations the agent's expertise, represented by the efficiency parameter θ, will have a stronger effect on the productivity of his own division than on that of his colleague's. Production function (2.1) captures this fact in the simplest possible manner by focusing on the case where the output of a given division is only affected by the efficiency parameter of the agent operating it. One would also expect that the effect of an agent's effort on the productivity of his division would be greater than its effect on the division operated by another agent; assuming otherwise would beg a question of why he was not assigned to the other division in the first place. In terms of the model, this means that $\alpha < \frac{1}{2}$.

The limiting case $\alpha = 0$ corresponds to a setting where both divisions are independent and thus the output of agent i is uninformative about the effort of agent j, $i \neq j$. On the other hand, when $0 < \alpha < \frac{1}{2}$, each of the two outputs provides information about both agents' efforts. In effect, the agents are now organized in a team: if either of them wants to collect information rent, he has to ensure cooperation of (i.e., collusion with) his colleague to do so. That is, the principal can use technological interdependency as an internal control that allows her to increase her expected payoff by (i) making sure that the agents have to collude if they want to shirk, and (ii) making collusion costlier for the agents. Indeed, an increase in α increases the agents' cost of collusion and makes it easier for the principal to prevent it. It is, therefore, natural to interpret α as a measure of intensity of internal control, with $\alpha = 0$ corresponding to the case of no internal control.

Owing to available technology, the principal may only be able to change the degree of productive interdependency within a certain range. Sometimes, as in the example with a purchasing manager on p. 7, by increasing the accuracy of the incoming inspection the principal can change α continuously. In other cases, as in the example with design and production engineers, she may not be able to alter it at all. To capture this possibility, I make the following assumption about the upper ($\overline{\alpha}$) and lower ($\underline{\alpha}$) bounds on α that are given exogenously:[7]

Assumption 1. $\alpha \in [\,\underline{\alpha}, \overline{\alpha}\,]$, *where* $0 \leqslant \underline{\alpha} \leqslant \overline{\alpha} < \frac{1}{2}$ *and* $\underline{\alpha} = \overline{\alpha} \Rightarrow \underline{\alpha} > 0$.

The principal chooses the intensity of internal control, α, and the accuracy of the accounting information system, $r(\cdot)$. Under the standard assumption that prices of the outputs are normalized to unity so that x^A and x^B represent both outputs and revenues, the principal's payoff is equal to the sum of the outputs net of monetary transfers, t^i, to the agents and is given by

$$\begin{aligned}\Pi(e^A, e^B) &= x^A(e^A, e^B) + x^B(e^A, e^B) - t^A(\mathbf{r}(\mathbf{x})) - t^B(\mathbf{r}(\mathbf{x})) \\ &= \theta^A + \theta^B + e^A + e^B - t^A(\mathbf{r}(\mathbf{x})) - t^B(\mathbf{r}(\mathbf{x}))\,.\end{aligned}$$

Under complete information, the principal requires both agents to exert the first-best effort levels of $e^A_{fb} = e^B_{fb} = 1$ and sets the transfers t^i such that the agents receive their reservation utility levels, which are normalized to zero. Under the first-best allocation, the agents' combined expected information rent, R_{fb}, is zero and agency welfare, $W \equiv R + \Pi$, is given by

$$W_{fb} = \Pi_{fb} = 1 + 2\,(\theta_l + \nu\Delta\theta)\,.$$

Following the tradition established in the literature on collusion, I assume that the agents can enter into a binding side contract that may be supported, for example, by a mechanism that makes such contract self-enforcing. I also assume that side transfers between the agents may involve transaction costs, i.e., the agents can make side transfers at a rate of $\frac{1}{1+\delta}$, $\delta \geqslant 0$.[8] It is worth noting that, in this setting, transfers do not have to take monetary form: since both agents are productive, one

[7]The requirement that $\alpha \neq \frac{1}{2}$ guarantees that simultaneous equations (2.1) have a non-degenerate solution; it is similar to Condition (C.2) in Ma (1988). The requirement that $\underline{\alpha} = \overline{\alpha} \Rightarrow \underline{\alpha} > 0$ rules out the uninteresting case where internal control is impossible. Otherwise, Assumption 1 is just a labeling convention and, as such, is made without loss of generality.

[8]The reader is referred to Tirole (1992) for an extended discussion of both assumptions.

can simply work in the other's division. The case of $\delta > 0$ then corresponds to a situation where, e.g., an agent is not as efficient working in his colleague's division as in his own.

Since the agents bargain over their collusive agreement under asymmetric information, the principal may be able to exploit the frictions in side contracting to make collusion more difficult. For example, Felli (1990) shows that, when each of the agents can renege on the side contract before he starts executing it, the principal can rule out collusion altogether at no cost. It is, however, very unlikely that, in real-life settings, the principal will be able to interfere in the mutual dealings between the agents to the extent sufficient to disrupt their collusive agreement. Following the path taken by most of collusion literature (and explicated in Tirole, 1992), I will take the "black-box" approach to side contracting and assume that, whenever the agents can benefit from collusion, they find a way to enter into a binding agreement so as to take advantage of the information asymmetry.[9] Since neither of the agents can collect an information rent unilaterally, I will also assume that they have equal bargaining power and thus share the proceeds from their collusive agreement equally. The allocations derived under this assumption thus characterize the lower bound of the principal's expected payoff and provide conservative estimates of the value of internal control.

The timing of the game is as follows:

0. The principal chooses α and $r(\cdot)$ that will be implemented.
1. Nature chooses the type of each agent. Each agent learns only his type.
2. The principal, who has all bargaining power, offers to the agents a grand contract specifying, for each agent, the action that should be taken and the corresponding compensation.
3. Each agent accepts or refuses the grand contract. If at least one agent refuses, the game ends and all parties receive their reservation utilities.
4. The agents negotiate over the side contract.

[9] An alternative approach is taken by Laffont and Martimort (1997), who assume that the side contract is designed by an uninformed third party, which is interpreted as a modeling device. A third party also appears in Laffont and Martimort (1998), where it is used to characterize the allocation in a centralized setting, and in Laffont and Martimort (2000) in a model of the provision of public goods.

5. Each agent accepts or refuses the side contract. If at least one agent refuses, the grand contract is played noncooperatively.
6. If the side contract has been accepted by both agents, the reports to the principal and transfers specified by the side contract are made.
7. The agents simultaneously produce their outputs and the transfers are executed according to the grand contract.

Formally, the side contract can be written as $\left\{\phi(\cdot), y^{ij}(\cdot), \tilde{e}^i(\cdot)\right\}$, where $\phi(\cdot)$ is the manipulation of the report sent to the principal, $y^{ij}(\cdot)$ are the transfers made from agent i to agent j, where $i, j = A, B$, $i \neq j$, and $\tilde{e}^i$ are the efforts supplied by agent i under the side contract. As shown by Tirole (1992), the *Collusion-Proofness Principle* (which is a version of the Revelation Principle) applies in this setting, and any final allocation that can be achieved by the side contract can also be achieved by the principal; hence the model can be represented by a direct mechanism in which the principal offers collusion-proof grand contracts. As a result, there is no collusion in equilibrium. I am interested in characterizing perfect Bayesian equilibria of the game in pure strategies.

I assume that at stage 1, when the principal makes a decision whether or not to implement internal controls, she can sign a binding agreement with the agents with respect to this decision only. That is, the agents negotiate with the principal in two stages, with the grand contract specifying effort levels and transfers being signed at stage 3. Sequential contracting of this sort, where decisions with respect to organizational structure and agents compensation are made at different times, are often observed in practice. For example, many contracts for lower-level employees stipulate a trial period that may range from several weeks to several years. The usual explanation is that in the course of the trial period employees have an opportunity to better learn the job; in terms of the model, it is during this period that the employee learns his type. It is also not uncommon for employment contracts with higher-level employees, such as top executives, to be negotiated over prolonged periods of time, with several stages of offers and counteroffers. Commitments made at earlier stages are then supported by reputation concerns.

2.3 Characterization

2.3.1 Benchmark Case: No Internal Control

As a benchmark, consider the case with no internal control (i.e., with $\alpha = 0$) where the principal faces two agents whose outputs are independent. Each agent, when he is efficient, can collect his information rent without interacting with his colleague, hence there is no scope for collusion. In this section, I assume that the principal has access to a perfect accounting information system (i.e., that $m(r) = 0$). In the absence of side contract, the Revelation Principle applies and, without loss of generality, the grand contract can be represented by a direct mechanism that specifies effort levels e_k and transfers t_k, where $k = h, l$, required of each of the agents when his efficiency parameter is θ_h and θ_l respectively. Since the principal observes the outputs but not the realizations of the efficiency parameters, the efficient agent can produce the output required of his inefficient colleague at a lower cost by exerting the effort of $e_l - \Delta\theta$. Define

$$\Phi(e) \equiv \tfrac{1}{2}(e)^2 - \tfrac{1}{2}(e - \Delta\theta)^2 \geqslant 0.$$

That is, $\Phi(e_l)$ denotes the amount of information rent collected by the efficient agent when he claims to be inefficient.

It is also convenient to introduce the following notation:

$$U_h = t_h - \tfrac{1}{2}\left(e_h\right)^2,$$
$$U_l = t_l - \tfrac{1}{2}\left(e_l\right)^2.$$

With this notation, one can write the incentive compatibility constraints as follows:

$$U_h \geqslant U_l + \Phi(e_l), \tag{2.2}$$
$$U_l \geqslant U_h - \Phi(e_h + \Delta\theta). \tag{2.3}$$

The participation constraints take the following form:

$$U_h \geqslant 0, \tag{2.4}$$

$$U_l \geqslant 0. \tag{2.5}$$

It is easy to check that only the incentive compatibility constraint for the efficient agent (2.2) and the participation constraint for the inefficient agent (2.5) are binding at the optimum. Substituting the binding constraints in the principal's objective function, one can write the principal's maximization problem as follows (the subscript stands for no control):

$$\max_{e_h, e_l} \quad \Pi_{NC} = \nu \left(\theta_h + e_h - \tfrac{1}{2}\left(e_h\right)^2 - \Phi\left(e_l\right)\right) + (1-\nu)\left(\theta_l + e_l - \tfrac{1}{2}\left(e_l\right)^2\right). \tag{2.6}$$

Notice that the effort level required of the inefficient agent, e_l, determines the amount of information rent collected by the efficient agent. Since this amount is increasing in e_l and the cost function is convex, the principal benefits from reducing e_l below the first-best level. At the optimum, her loss in productivity from an inefficiently low level of e_l just equals her benefit from reducing the efficient agent's information rent. Maximizing (2.6) with respect to the agents' effort levels yields the following solution:

$$\begin{aligned} e_h &= 1 = e_{fb}\,, \\ e_l &= 1 - \Delta\theta \frac{\nu}{1-\nu}. \end{aligned} \tag{2.7}$$

That is, an efficient agent exerts the first-best level of effort and collects his information rent, regardless of the type or actions of his colleague: there is no scope for collusion. An inefficient agent exerts effort that is strictly lower than the first-best and collects no information rent.

In what follows I assume that $e_l \geqslant 0$, i.e., shutdown is never optimal and the principal employs agents of both types (the necessary conditions are stated formally in Assumption 2). It is straightforward to show that productive efficiency E_{NC}, the principal's expected payoff Π_{NC}, the agents' information rent R_{NC}, and agency welfare W_{NC} under this contract are given by

$$E_{NC} = 2\left(1 - \nu\Delta\theta\right), \tag{2.8}$$

$$\Pi_{NC} = 1 + 2\theta_l + (\Delta\theta)^2 \frac{\nu}{1-\nu}, \tag{2.9}$$

$$R_{NC} = \Delta\theta\nu \left(2 + \Delta\theta - \frac{2\Delta\theta}{1-\nu}\right), \tag{2.10}$$

$$W_{NC} = 1 + 2\theta_l + 2\nu\Delta\theta - (\Delta\theta)^2 \frac{\nu^2}{1-\nu}, \tag{2.11}$$

where the subscripts stand for no control.

It is instructive to rewrite the principal's expected payoff as follows:

$$\Pi_{NC} = \underbrace{2\left[\nu\left(\theta_h + e_h - \tfrac{1}{2}(e_h)^2\right) + (1-\nu)\left(\theta_l + e_l - \tfrac{1}{2}(e_l)^2\right)\right]}_{\text{Expected agency welfare}^{10}} - \underbrace{2\nu\Phi(e_l)}_{\substack{\text{Expected}\\ \text{information rent}}}.$$

A social utility maximizer putting equal weights on all parties' expected payoffs would ignore the distribution of information rents between the principal and two agents (viewed as a group) and maximize expected agency welfare only. In this case, asymmetric information would have no effect on the output level because the first-best levels of effort would be chosen. In contrast, the principal maximizes her expected payoff — and, therefore, is willing to accept some downward distortion away from the socially efficient effort level in order to decrease the agent's expected information rent. As a consequence, under asymmetric information both productive efficiency and agency welfare — the two measures that characterize the resultant allocation — are below the corresponding socially efficient levels.

The above-mentioned measures capture different properties of the principal–agent relationship. Productive efficiency, E, measures the expected level of output but ignores the cost of producing it. In settings with asymmetric information, consumers suffer from underproduction and thus benefit from any increase in productive efficiency. The important limitation of this measure, however, is that the model, set in a partial equilibrium framework, is silent about the value that consumers derive

[10] Some authors use the term *allocative efficiency*: see, e.g., Laffont and Martimort (2002).

from this increase. On the other hand, agency welfare, W, accounts for expected output net of the technological cost and, therefore, characterizes the social value of the contractual relationship.

2.3.2 The Case with Internal Control

Consider now the case where the principal uses internal control (i.e., $\alpha > 0$). Since output $\mathbf{x}$ is now a function of the efforts supplied by both agents, neither of them can collect any information rent unless they coordinate their efforts. For some realizations of the efficiency parameters, the agents may benefit only if they can also make transfers. Thus in a setting where collusion is impossible — i.e., the agents can neither effect transfers nor communicate with each other — the principal offers the agents a grand contact (which I label C_0) specifying, for all possible realizations of the efficiency parameters, the first-best effort levels and transfers that just compensate the agents for their efforts, with penalties for any realization of the output $\mathbf{x}$ not prescribed by the contract.

It is easy to see, however, that this contract is not incentive compatible if the agents can collude (I consider the case with no collusion in Chapter 3). A *collusion-proof* grand contract, therefore, has to guarantee the agents the payoffs at least as high as the ones that they would collect if they were to collude. The grand contract, which I label C_1, specifies effort levels and transfers for each of the four possible reports on agents' types: $\left\{e^A_{jk},\, t^A_{jk}, e^B_{jk},\, t^B_{jk}\right\}$, where the subscripts $j, k = l, h$ denote the types of agents A and B respectively. To provide a benchmark setting where the organization has a "flat" (as opposed to hierarchical) organizational structure, I will assume in this section that the principal offers a grand contract that is *symmetric* with respect to the agents' identities. This assumption can also be interpreted as representing cultural or institutional constraints: for example, in government agencies and many European organizations (notably, universities) there exist severe restrictions on the maximum pay difference for employees occupying identical positions. This assumption will be relaxed in Chapters 3 and 4.

As a practical matter, the symmetry of the grand contract allows me to simplify the notation by adopting, until the symmetry assumption is relaxed, the following notational convention:

$$\begin{aligned} e^A_{hh} &= e^B_{hh} \equiv e_{hh}, \\ e^A_{hl} &= e^B_{lh} \equiv e_{hl}, \\ e^A_{lh} &= e^B_{hl} \equiv e_{lh}, \\ e^A_{ll} &= e^B_{ll} \equiv e_{ll}. \end{aligned}$$

I use double indices to denote the case with internal control and single indices — the case with no internal control.

Since the reports to the principal are made after the agents enter the side contract and learn each other's types, the agents' participation and incentive compatibility constraints have to be satisfied for each possible realization of the efficiency parameters. The participation constraints are given by

$$t_{jk} - \tfrac{1}{2}\left(e_{jk}\right)^2 \geqslant 0\,, \tag{2.12}$$

where $j, k = h, l$.

With $\alpha > 0$, incentive compatibility constraints take different forms depending on the parameters of the model and the realization of the agents' types. First, consider the case where both agents are efficient: I will call it the hh-case since both productivity parameters take their high values. Production function (2.1) allows the agents to pretend that both of them are inefficient and collect $\Phi\big(e_{ll}\big)$ each.[11] Hence in the hh-case, the side contract specifies

$$\left\{\phi(\hat{\theta}^A_h, \hat{\theta}^B_h) = (\theta_l, \theta_l),\ y^{AB} = y^{BA} = 0,\ \tilde{e}^A = \tilde{e}^B = e_{ll}\right\}.$$

That is, both agents exert effort of e_{ll} and there are no transfers. The grand contract, therefore, has to satisfy the following incentive compatibility constraint:

$$t_{hh} - \tfrac{1}{2}\left(e_{hh}\right)^2 \geqslant t_{ll} - \tfrac{1}{2}\left(e_{ll}\right)^2 + \Phi\left(e_{ll}\right). \tag{2.13}$$

Consider now the case where only one agent, i, is efficient: in this chapter, I will call it the hl-case regardless of the identity of agent i. If agent i claims to

[11] As we shall see presently, in a generic case $e_{ll} \neq e_l$ and thus $\Phi\left(e_{ll}\right) \neq \Phi\left(e_l\right)$.

be inefficient and decreases his level of effort by $\Delta\theta$, the output of division j will decrease by $\alpha\Delta\theta$, giving away the deviation and the identity of its perpetrator. Agent i, however, can ask his colleague to exert additional effort to make up for this deficiency and compensate him for the inconvenience. If the level of productive interdependency α is sufficiently small, the machination will be profitable — albeit less so than in the *hh*-case. Since, for the deviation to remain undetected by the principal the levels of output under this collusive agreement should be the same as in the *ll*-case, the new effort levels, $\hat{e}^i$ and $\hat{e}^j$, must satisfy the following conditions:

$$\begin{aligned} \Delta\theta + (1-\alpha)\hat{e}^i + \alpha\hat{e}^j &= e_{ll}\,, \\ \alpha\hat{e}^i + (1-\alpha)\hat{e}^j &= e_{ll}\,, \end{aligned} \tag{2.14}$$

where $i, j = A, B$ and $i \neq j$. The solution to (2.14) is given by

$$\begin{aligned} \hat{e}^i &= e_{ll} - \Delta\theta\frac{1-\alpha}{1-2\alpha}\,, \\ \hat{e}^j &= e_{ll} + \Delta\theta\frac{\alpha}{1-2\alpha}\,. \end{aligned} \tag{2.15}$$

Changing variables, define

$$\begin{aligned} \Psi(e) &\equiv \frac{1}{2}e^2 - \frac{1}{2}\left(e - \Delta\theta\frac{1-\alpha}{1-2\alpha}\right)^2, \\ \psi(e) &\equiv \frac{1}{2}\left(e + \Delta\theta\frac{\alpha}{1-2\alpha}\right)^2 - \frac{1}{2}e^2\,. \end{aligned}$$

Here, $\Psi(\cdot)$ denotes cost savings for the efficient agent in the *hl*-case when he claims to be inefficient and $\psi(\cdot)$ denotes additional cost incurred by the inefficient agent for which he has to be compensated. To simplify the analysis, I make the following assumption:[12]

Assumption 2. *If* $\alpha = 0$*, then* $e_l - \Delta\theta \geqslant 0$*. If* $\alpha > 0$*, then* $e_{ll} - \Delta\theta\frac{1-\alpha}{1-2\alpha} \geqslant 0$.

Under the side contract, the agents share the proceeds from their collusive action equally. Thus, with transaction cost $\delta \geqslant 0$, the transfer from the efficient

[12] This assumption can be relaxed at the expense of introducing additional nonnegativity conditions in the appropriate incentive compatibility constraints. Doing so complicates the computation without changing the qualitative nature of the results.

agent i to his colleague, y^{ij}, has to satisfy the following condition:

$$\Psi(e_{ll}) - y^{ij} = \frac{1}{1+\delta}\, y^{ij} - \psi(e_{ll}). \tag{2.16}$$

Solving (2.16) for y^{ij}, we find that $y^{ij} = \frac{1+\delta}{2+\delta}\left(\Psi(e_{ll}) + \psi(e_{ll})\right)$ and the information rent collected by each agent when they collude is given by $\frac{1}{2+\delta}\left(\Psi(e_{ll}) - (1+\delta)\psi(e_{ll})\right)$. It is convenient to introduce the following notation:

$$\mathcal{R}(\cdot) \equiv \Psi(\cdot) - (1+\delta)\psi(\cdot). \tag{2.17}$$

Clearly, the agents will not engage in collusion in the *hl*-case if they are worse off as a result. Therefore, the side contract has to satisfy the following acceptance constraint:

$$\mathcal{R}(e_{ll}) \geqslant 0. \tag{2.18}$$

The side contract will take one of two different forms, depending on the values of the parameters. When the cost of collusion, as determined by α and δ, is sufficiently low so that constraint (2.18) is not binding, collusion occurs in both *hh*- and *hl*-cases, i.e., whenever at least one of the agents is efficient; I will call the corresponding set of parameters the *full collusion* (FC) region. Since my goal is to characterize the lower bound of the principal's payoff attainable under various organizational arrangements, I will in what follows focus primarily on this region of parameters. The side contract prescribes

$$\left\{\phi(\hat{\theta}^i_h, \hat{\theta}^j_l) = (\theta_l, \theta_l),\ y^{ij} = \frac{1+\delta}{2+\delta}\left(\Psi(e_{ll}) + \psi(e_{ll})\right),\ y^{ji} = 0,\ \tilde{e}^i = \hat{e}^i,\ \tilde{e}^j = \hat{e}^j\right\},$$

where $\hat{e}^i$, $\hat{e}^j$ are given by (2.15). The grand contract, therefore, has to satisfy the following incentive compatibility constraints to be collusion proof:

$$t_{hl} - \frac{1}{2}\left(e_{hl}\right)^2 \geqslant t_{ll} - \frac{1}{2}\left(e_{ll}\right)^2 + \frac{1}{2+\delta}\mathcal{R}(e_{ll}), \tag{2.19}$$

$$t_{lh} - \frac{1}{2}\left(e_{lh}\right)^2 \geqslant t_{ll} - \frac{1}{2}\left(e_{ll}\right)^2 + \frac{1}{2+\delta}\mathcal{R}(e_{ll}). \tag{2.20}$$

When the cost of collusion is sufficiently high and constraint (2.18) is binding, the agents collude only in the *hh*-case. I will call the corresponding set of parameters the *partial collusion* (PC) region. Figure 2.1 shows that, for intermediate values of probability ν, the full collusion region becomes smaller as transaction cost δ increases. In the partial collusion region, there is no profitable deviation for the agents in the *hl*-case and, by the standard assumption that, when indifferent, the agents act in the best interest of the principal, the side contract specifies truthful reports and zero transfers:

$$\left\{\phi(\hat{\theta}^i, \hat{\theta}^j) = (\theta^i, \theta^j),\ y^{ij} = y^{ji} = 0,\ \tilde{e}^i = e^i,\ \tilde{e}^j = e^j\right\}.$$

The incentive compatibility constraints in the grand contract then take the following form:

$$\begin{aligned} t_{hl} - \tfrac{1}{2}\left(e_{hl}\right)^2 &\geqslant t_{ll} - \tfrac{1}{2}\left(e_{ll}\right)^2, \\ t_{lh} - \tfrac{1}{2}\left(e_{lh}\right)^2 &\geqslant t_{ll} - \tfrac{1}{2}\left(e_{ll}\right)^2. \end{aligned}$$

Since in the *ll*-case there is no profitable deviation either, the agents also report their types truthfully.

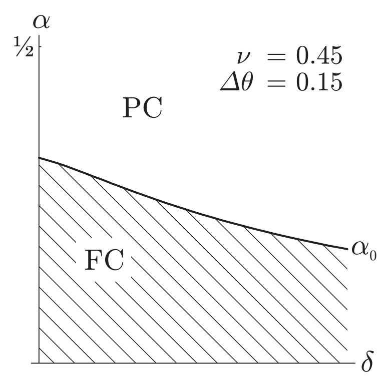

Figure 2.1: Two regions in δ–α space; α_0 solves (2.18) written with equality.

Consider now the agents' decisions to accept the side contract at stage 5 when each of them only knows his own type. From the discussion above it is clear that the efficient agent always strictly prefers to enter the side contract — but, in the partial collusion region, the inefficient agent is indifferent between entering into a collusive agreement and signing the grand contract with the principal directly.

Notice, however, that in this case both agents collect zero information rents and the principal does not benefit by using this indifference to extract the information from the inefficient agent. On the other hand, in the full collusion region both agents strictly prefer to enter the side contract. It is, therefore, without loss of generality to assume that the agents always accept the side contract.

2.3.3 Results

The principal's problem is to choose e_{jk} and t_{jk}, where $j, k = h, l$, so as to maximize

$$\begin{aligned}\Pi_{C_1} &= 2\nu^2 \left(\theta_h + e_{hh} - t_{hh}\right) \\ &\quad + 2\nu \left(1-\nu\right)\left(\theta_h + \theta_l + e_{hl} - t_{hl} + e_{lh} - t_{lh}\right) \\ &\quad + 2\left(1-\nu\right)^2 \left(\theta_l + e_{ll} - t_{ll}\right)\end{aligned} \tag{2.21}$$

subject to (2.12), (2.13), (2.18), (2.19) and (2.20).

The solution to (2.21) is given in Lemma 1.

Lemma 1. *Under the optimal collusion-proof contract with internal control, C_1:*

1. *The effort levels are given by:*

$$e_{hh} = e_{hl} = e_{lh} = 1 = e_{fb}\,;$$

   (a) *In the full collusion (FC) region:*

$$e_{ll} = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2}\left\{1 - \delta\,\frac{1-\nu}{(2+\delta)(1-2\alpha)}\right\};$$

   (b) *In the partial collusion (PC) region:*

$$e_{ll} = 1 - \Delta\theta \frac{\nu^2}{(1-\nu)^2}.$$

2. *The full collusion region is characterized by $\alpha \leqslant \alpha_0$, where*

$$\alpha_0 = \frac{(4+\delta)(1-\nu)^2 - \Delta\theta\left(1 + 2\nu(1+\delta) + \nu^2(1-\delta)\right) - \sqrt{M}}{(2+\delta)\left(4(1-\nu)^2 - \Delta\theta\big(1 + \nu\left(2 + \nu + 2\delta(1-\nu)\right)\big)\right)}$$

and

$$M = \big((4+\delta)(1-\nu)^2 - \Delta\theta\big(1+2\nu(1+\delta)+\nu^2(1-\delta)\big)\big)^2 \\ -(2+\delta)\left((2-\Delta\theta)(1+\nu^2)-4\nu\right)\left(4(1-\nu)^2-\Delta\theta\left(1+\nu\big(2+\nu+2\delta(1-\nu)\big)\right)\right).$$

Proof. See Appendix. □

Under the contract with no internal control (NC) the principal trades off her benefit from reducing the information rent accruing to the efficient agents against the loss from setting the efforts required of the inefficient agents below the first-best level. When the principal implements internal control, she requires the first-best effort of both agents not only in the *hh*-case, which occurs with probability ν^2, but, in addition, in the *hl*-case, which occurs with probability $2\nu(1-\nu)$. That is, lowering e_{ll} reduces information rents in both of these cases and requires inefficiently low effort levels of both agents only in the *ll*-case, which occurs with probability $(1-\nu)^2$. One would, therefore, expect the principal to be better off when she implements internal control. The following result demonstrates that this conjecture is correct — but, under certain conditions, she can do even better by offering the agents a different contract.

Proposition 1. *The allocations attainable under the contract with no internal control (NC) and the contract with internal control (C_1) have the following properties:*

1. *With respect to productive efficiency:*
   (a) *In the FC region: $E^{FC}_{C_1} - E_{NC} \geqslant 0$, with strict inequality for $\delta > 0$;*
   (b) *In the PC region: $E^{PC}_{C_1} - E_{NC} > 0$.*
2. *With respect to the principal's expected payoff: $\Pi_{C_1} - \Pi_{NC} > 0$.*
3. *With respect to agency welfare:*
   (a) *In the FC region: $W^{FC}_{C_1} - W_{NC} \gtreqless 0 \Leftrightarrow \alpha^\star_{C_1} \gtreqless 0$, where*

$$\alpha^\star_{C_1} = \frac{4\nu + 2\delta\nu(3+\nu) - \delta(2+\delta)\big(\sqrt{(1-\nu)^3}+1\big)}{2\nu(2+\delta)^2};$$

(b) In the PC region: $W_{C_1}^{PC} - W_{NC} \gtreqqless 0 \Leftrightarrow \nu \lesseqqgtr \frac{1}{2}(\sqrt{5}-1)$.

Proof. See Appendix. $\square$

According to Proposition 1, internal control (weakly) improves productive efficiency and, under the contract C_1 described on pp. 21 – 24, the principal is strictly better off implementing it. In fact, the following result holds:

Corollary 1. *In the full collusion region,* $\dfrac{\partial}{\partial \alpha}\Pi_{C_1}^{FC} > 0$.

Proof. See Appendix. $\square$

In other words, whenever the agents find it relatively easy to collude and the principal chooses to implement internal control (i.e., in the full collusion region) she always prefers to increase its intensity to the maximum level, $\overline{\alpha}$, allowed by the available technology. Notice that there is no benefit for the principal in increasing the intensity of internal control beyond α_0 since her expected payoff in the partial collusion region does not depend on α. If, however, $\overline{\alpha}$ is not too high and collusion is relatively costly to prevent, implementing internal control *decreases* agency welfare. The result highlights the difficulty faced by the regulator: implementing internal control always benefits one group of a company's stakeholders — consumers — by increasing productive efficiency (provided $\delta > 0$) but sometimes is harmful for two other important groups, shareholders and employees, because it decreases the sum of profits accruing to these two groups.

The loss in agency welfare given by $W_{NC} - W_{C_1}$ represents a *structural* cost, which obtains even in the absence of implementation and reporting costs. However, as collusion becomes costlier for the agents — and, in particular, as the intensity of internal control increases — so does agency welfare: see Figure 2.2).

It follows from Proposition 1 that, when agency welfare is lower with internal control than without (i.e., $W_{C_1} < W_{NC}$), the agents' loss from internal control exceeds the principal's gain. The principal thus can increase her expected payoff relative to the contract C_1 if she can extract from the agents the surplus that obtains when internal control is not implemented. As shown in the proof of Proposition 2

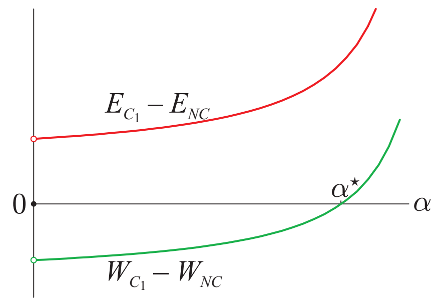

Figure 2.2: The effect of internal control on productive efficiency E and agency welfare W in the FC region with $\delta > 0$. The value of $\alpha^\star$ is given in Proposition 1.

in the Appendix, the agents' expected information rent is always strictly less with internal control than without, i.e., $R_{NC} > R_{C_1}$. Therefore, at stage 1 when the principal makes a decision with respect to internal control and the agents have not yet learned their types, each of them is willing to pay the principal up to the amount of $\frac{1}{2}(R_{NC} - R_{C_1}) > 0$ — or, equivalently, agree to make salary concession in the same amount at stage 3 when they negotiate over the grand contract — if she does not implement internal control. When $W_{C_1} < W_{NC}$ (i.e., when $\overline{\alpha} < \alpha^\star$: see Figure 2.3), the principal prefers to accept their offer, provided the agents' commitment is credible. I will label this new contract C_2. The result that obtains when the principal extracts the surplus is stated formally below.

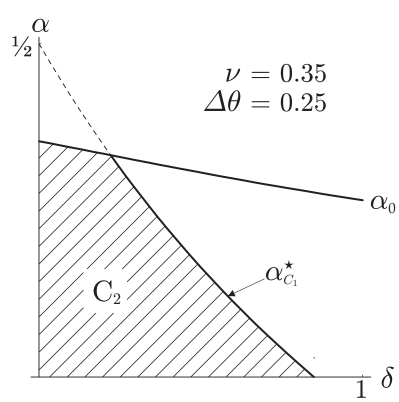

Figure 2.3: The region, in δ–α space, where the principal offers contract C_2; $\alpha^\star_{C_1}$ is given in Proposition 1.

Proposition 2. *When internal control decreases agency welfare, the principal's expected payoff is higher under contract C_2 than under contract C_1. That is,*

$$W_{NC} > W_{C_1} \Rightarrow \Pi_{C_2} > \Pi_{C_1}.$$

Proof. See Appendix. $\square$

In other words, the *ability* to implement internal control is always valuable to the principal, but the decision to actually implement it depends on transaction costs, the properties of available technology, and the characteristics of feasible contractual arrangements. In particular, the easier it is for the agents to enter into a collusive agreement, the *less* likely is the principal to implement internal control.

It can also be shown that, as ν increases, the principal is more likely to find herself either in the full collusion (FC) region where $W_{NC} > W_{C_1}^{FC}$ and she offers contract C_2, or in the partial collusion (PC) region, where for sufficiently high values of ν she also offers contract C_2. That is, the more likely it is that an agent is efficient, the less likely is the principal to use internal control. Situations with relatively high values of ν will be observed, e.g., when there exists an effective but imperfect mechanism of screening the agents for high productivity.

To summarize, implementing internal control has markedly different consequences for shareholders and managers depending on the technological and organizational characteristics of the firm and the pool of job candidates. In particular, the results demonstrate that company characteristics other than size can have a direct bearing on the type of internal controls that best serves the interests of shareholders. The proximity to the operations allows external and (especially) internal auditors to evaluate these characteristics and attest to the adequacy of the internal control system. The attestation process, however, turns out to be more involved than initially envisioned by the regulators, and the precipitous rise in audit fees reported in recent years may, indeed, be commensurate with the increase in audit costs.

The results reported in this chapter also demonstrate that requiring companies to implement internal control (e.g., by regulation) provides them with incentives to reduce implementation costs but has very limited effect, if at all, on the magnitude of structural costs that stem from the organizational arrangement and informational structure. In fact, to the extent that better information technology facilitates side contracting and reduces transaction costs δ, the number of companies that prefer not to implement internal control may actually increase over time.

2.4 The Role of Accounting Information System

Consider now the case where $W_{NC} - W_{C_1}^{FC}(\overline{\alpha}) > 0$ and $\underline{\alpha} > 0$, i.e., the principal prefers not to implement internal control but available technology does not allow her to get rid of productive interdependency completely. The agents will only agree to make salary concessions and sign contract C_2 if she can credibly commit to ignore all information provided by the internal control system. Specifically, when she observes

$$x^i = \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} \pm \alpha\Delta\theta,$$

the levels of output in the *hl*-case when the efficient agent claims to be inefficient, she has to act as if she has observed

$$x^i = \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu},$$

the level of output in the *ll*-case when both agents exert the level of effort given by (2.7). If commitment of this sort cannot be made, the agents will collude and the principal's expected payoff will be Π_{C_1}. Under certain conditions, however, she may be able to overcome the lack-of-commitment problem and strictly increase her expected payoff by *decreasing* the accuracy of the accounting information system, as the following result demonstrates.

Proposition 3. *There exists a set of parameters with non-empty interior and reporting functions r_0, r_1 such that $m(r_1) > m(r_0)$ and $\Pi(r_1) > \Pi(r_0)$.*

Proof. See Appendix. □

Here, again, the principal uses her ability to install a more accurate information system as a threat in negotiating with the agents but in fact installs a less accurate one. Notice that reducing the accuracy of the information system predictably leads to a loss in productive efficiency because the effort level required of the agents when both of them are inefficient is lower than the corresponding effort level in the benchmark case. The result has implications for the problem of establishing materiality thresholds in financial reporting. In the Statement of Financial Accounting Concepts No. 2, FASB argues that the degree of precision of the accounting information system is a factor in materiality judgments (FASB, 1980, §130). In this model, the degree of precision (i.e., the margin of error) is determined endogenously.

It follows immediately from Proposition 3 that, if a more accurate information system is not available, the principal will be willing to invest up to the amount given by (A.9) in the Appendix in a more accurate system that will only be used as a threat and never actually installed. This investment is a deadweight loss because it does not improve productive efficiency (the effort levels are the same under both systems) and is only used to redistribute the agents' information rent.

Proposition 3 is related to the result reported in Arya, Glover, and Sunder (1998), who show, in a moral hazard framework, that an accounting information system with earnings management may help the principal overcome the lack-of-commitment problem by delaying her decision to fire an under-performing agent and thereby providing him with a stronger *ex ante* incentive to work hard. One difference, aside from the setting, between the model by these authors and the one studied here concerns the properties of the accounting information system in question. In Arya *et al.* (1998), in the managed earnings setting the information system *aggregates* earnings over two periods: the principal observes the sum of the two earnings figures at the end of the second period. That is, information is delayed but none of it is lost. In contrast, in my model the information system *distorts* (or garbles) the output figures and some information is lost as a result.

2.5 Discussion

All internal controls share the property that, when implemented, they create a scope for collusion between (or among) the agents. In this chapter I investigate a model where the agents do not abuse internal control for personal gains but may collude to mitigate its effect on their ability to shirk. Internal control studied in this chapter provides two potential benefits to the principal: (i) it forces the agents to collude if they want to collect information rents and thereby reduces their benefit from shirking and (ii) it serves as an additional source of information about their effort levels. As a result, internal control makes is easier for the principal to reduce the agents' information rents. However, it also comes at a cost of reducing agency welfare (I call it *structural* cost) that does not disappear even when internal control is costless to implement. When collusion is relatively easy (and, therefore, difficult to prevent), this cost outweighs both of the above-mentioned benefits.

Under certain conditions, the principal is able to extract from the agents the surplus that obtains when internal control is not implemented and increase her expected payoff relative to the case with internal control. That is, internal control is always valuable to the principal — but she sometimes prefers to use it as a threat without actually implementing it. The model demonstrates that, the easier it is for the agents to collude, the *less* likely is the principal to implement internal control, provided that the credible commitment by the agents is possible. I also show that the principal may benefit from reducing the accuracy of the accounting information system. This chapter provides a natural setting where the problem of the principal's inability to commit to ignore the information provided by the internal control system can be remedied by reducing its accuracy.

In this chapter I focus on a centralized setting where the agents can sign binding collusive agreements — i.e., there are no frictions in side contracting. From a methodological standpoint, the "black-box" approach to modeling the agents' negotiation over the side contract can be seen as a reduced form of a more comprehensive model where the bargaining over the side contract is studied explicitly. As a result, the model characterizes the upper bound of the agents' (collective) gain from collusion (corresponding to the lower bound of the value of internal control to the principal) and is consistent with the approach typically taken in the collusion literature (see, e.g., Laffont and Martimort, 1998). The pervasive nature of collusion in organizations is a well-documented phenomenon (see, e.g., Tirole, 1986); hence the natural question to ask is, what can be done to minimize its detrimental effect? I investigate several avenues that the principal can pursue in response to the threat of collusion in Chapter 4.

Chapter 3

Additional Properties of Internal Control

As shown in Chapter 2, the value of internal control to the principal depends on transaction costs of collusion, δ, which determine how easy it is for the agents to exchange transfers. One interpretation of transaction costs is that each agent simply finds it easier to work in his department than in his colleague's. Following Tirole (1992), one can also interpret transaction costs as a reduced form of modeling frictions in side contracting. A more literal interpretation that monetary transfers are infeasible and "in-kind" transfers entail losses is also consistent with the model.

In this chapter, I investigate side contracting in more detail by explicitly considering the role that communication between the agents plays in making collusion feasible. In Chapter 2, side contracting between the agents was frictionless, hence the resultant allocation characterized the upper bound of the principal's loss from collusion. To determine the sensitivity of internal control to individual components of side contracting, in section 3.1, I consider the (benchmark) case where communication between the agents is infinitely costly, ruling out collusion altogether. I show that, for a wide range of parameters, the principal in this case attains the first-best allocation. I then discuss the extent to which the principal can take advantage of internal control in real-life settings where the cost of communication between the agents takes intermediate values.

In Section 3.2, I focus on one avenue of increasing the value of internal control available to the principal: the choice of an organizational arrangement. I relax the assumption adopted in Chapter 2 that the contracts offered to the agents are symmetric and show that the principal benefits from treating the agents asymmetrically, but only if $\delta > 0$. I then discuss the implications of using transaction costs as a shortcut to modeling contracting frictions. In Section 3.3 I investigate the properties of production function (2.1) and the extent to which the results are sensitive to its properties. Section 3.4 concludes.

3.1 The Cost of Horizontal Communication

Thus far, I have considered the settings where transfers between the agents are subject to (exogenous) transaction costs $\delta \geqslant 0$, which, *inter alia*, represent the frictions in side contracting, but communication between the agents is costless. This approach is standard in models of collusion (see, e.g., Laffont and Meleu, 1997) and can be justified by appealing to practice where it usually is easier for the agents to communicate with one another than with the principal but the principal has an advantage in effecting transfers. The assumption that horizontal communication is costless can then be seen as simply a convenient normalization. It has, however, been shown in the literature (see, e.g., Laffont and Martimort, 1998) that the allocations attainable under the threat of collusion are sensitive to the type of communication mechanism available to the agents. In this section, I investigate the effect of horizontal communication on the value of internal control.

The frictions in communication between employees can take various forms, from literal misunderstanding when, say, both speak English as a second language, to inability to convey information, such as the details of the contract with the principal, in a credible way. Even though in most real-life settings the costs of communication fall somewhere on the continuum between zero and infinity, considering the extreme case of no communication suffices to characterize the effect of these costs on internal control. It should be noted, however, that the principal will usually have a limited ability to change these costs. Furthermore, it can be argued that internal control is effective in limiting the agents' ability to engage in inappropriate behavior precisely because they are in a better position to control — and hence communicate with —

each other than the principal. Nonetheless, considering the case where the lack of horizontal communication rules out collusion altogether is instructive because it provides a useful, if rarely attainable in practice, benchmark that characterizes the upper bound of the value of internal control. Consistent with this goal, in this section I will confine attention to identifying conditions that allow the principal to implement the first-best allocation.

Consider the following version of the model introduced in Chapter 2.

0. The principal implements $\alpha > 0$.
1. Nature chooses the type of each agent. Each agent learns only his type.
2. The principal offers to the agents a contract specifying, for each agent, the action that should be taken and the corresponding compensation.
3. Each agent accepts or refuses the grand contract. If at least one agent refuses, the game ends and all parties receive their reservation utilities.
4. If both agents have accepted the contract, each submits to the principal his report, without observing the report submitted by the other agent.
5. The agents simultaneously produce their outputs and the transfers are executed.

Since the agents cannot communicate, they also cannot exchange transfers, and thus a feasible deviation from the effort levels specified in the contract is only possible in the *hh*-case (recall from Chapter 2 that when only one of the agents is efficient, a deviation by either of them will be detected unless they coordinate efforts and exchange transfers). When both agents deviate and collect information rents, we observe what is known as *tacit* collusion (see, e.g., Mookherjee, 1984, and Arya, Glover, and Hughes, 1997) because the agents arrive at a mutually beneficial outcome without coordinating their actions explicitly. Since the agents do not interact and are *ex ante* symmetric, there is no loss of generality in looking for a solution in the set of symmetric equilibria.

By the Revelation Principle, the contract can be represented by a direct mechanism where each of the agents submits to the principal a report on his type. The contract specifies the effort levels as a function of the report and transfers as a function of both outputs. To implement the first-best allocation, the principal requires the effort of $e_{fb} = 1$ of both types of the agents. To see why each of the transfers is a function of both outputs, suppose that agent i is efficient and deviates from his contractual effort level of 1 by exerting the effort of $1 - \Delta\theta$. Instead of observing the outputs consistent with the contract, given by

$$x^A = \theta_h + 1, \quad x^B = \theta^B + 1,$$

where $\theta^B = \theta_l, \theta_h$, the principal will observe

$$x^A = \theta_l + 1 + \alpha\Delta\theta, \quad x^B = \theta^B + 1 - \alpha\Delta\theta.$$

Assumption 1 guarantees that she is able to determine the identity of the agent who has "shirked."

Following Kofman and Lawarrée (1993), in this section I assume that the principal can impose a penalty, P, on the agent found in breach of contract but the penalty cannot exceed an exogenously given value of $P^m \geqslant 0$. I also assume that the penalty is independent of the transfer compensating the agent for the exerted effort.[1] As shown in Baron and Besanko (1984), the principle of maximum deterrence applies in this setting, hence it suffices to consider the case where the principal applies the highest possible penalty to the agent found in breach of contract, i.e., $P = P^m$. With these assumptions, the contract offered by the principal, which I label $\mathrm{C_B}$ (for benchmark), takes the following form:

$$\left\{ e = 1,\ t_c = \frac{1}{2},\ t_b = \frac{1}{2} - P^m \right\},$$

where t_c denotes the transfer to the agent who complies with the contract and t_b is the transfer to the agent who is found to have violated it.

An inefficient agent accepts contract $\mathrm{C_B}$, which, provided that he exerts the required effort level, guarantees him his reservation utility regardless of the type and the effort level taken by his colleague. In the presence of internal control, the inefficient agent does not have profitable deviations, hence the contract is also incentive compatible. Consider now the problem faced by an efficient agent i, $i = A, B$, and

[1] That is, the agent is always compensated for his effort but, if found in breach of contract, pays P to the principal. A very similar result obtains when the principal withholds the compensation for the effort when the agent violates his contractual obligation; naturally, the set of the parameters where the first-best allocation is attainable is bigger in that case.

suppose that he accepts the contract and pursues the following strategy with respect to the effort level: he deviates from the contract (i.e., chooses $e = 1 - \Delta\theta$) with probability $\lambda \in [0,1]$ and exerts the contractual effort level with probability $1-\lambda$. This strategy is supported by (consistent) beliefs: $\Pr\left\{e^j = 1-\Delta\theta \,|\, \theta^j = \theta_h\right\} = \lambda$ and $\Pr\left\{e^j = 1 \,|\, \theta^j = \theta_h\right\} = 1-\lambda$, where $j = A, B$ and $j \neq i$.

Denote by U_h the expected payment to the efficient agent net of the cost of effort. With probability ν^2 both agents are efficient; when this is the case, with probability λ^2 both deviate from the contract and collect the information rent given by $\Phi(1)$. With probability $\nu(1-\nu)$, one of the agents deviates and the other does not; in this case the deviating agent pays the penalty and the agent who sticks with the contract receives zero rent. Finally, with probability $(1-\nu)^2$ both agents exert the contractual effort levels and face neither rent nor penalty. Next, with probability $(1-\nu)$, agent j is inefficient and agent i pays the penalty whenever he deviates, i.e., with probability λ. To summarize, the efficient agent's expected net payment is given by:

$$\begin{aligned} U_h &= \nu\left(\lambda^2\Phi(1) - \lambda(1-\lambda)P^m\right) - (1-\nu)\lambda P^m \\ &= \frac{1}{2}\lambda\left[\lambda\nu\big(2P^m + \Delta\theta(2-\Delta\theta)\big) - 2P^m\right]. \end{aligned}$$

Observe that

$$\frac{\partial^2}{\partial\lambda^2}U_h = \nu\left(2P^m + \Delta\theta(2-\Delta\theta)\right) > 0\,,$$

where the inequality follows because, by Assumption 2, $\Delta\theta \leqslant 1$. That is, U_h is a convex function of λ and it suffices to consider two limiting cases, $\lambda = 0$, where the efficient agent always deviates, and $\lambda = 1$, where he always performs pursuant to the contract.

Never deviating (i.e., choosing $\lambda = 0$) guarantees the efficient agent his reservation utility, hence the participation constraint is satisfied. For contract $\mathrm{C_B}$ to be incentive compatible, the following condition should hold:

$$U_h|_{\lambda=1} = \frac{1}{2}\nu\Delta\theta(2-\Delta\theta) - P^m(1-\nu) \leqslant 0. \tag{3.1}$$

The analysis above leads to the following result:

Proposition 4. *Under contract C_B, the principal attains the first-best allocation if* *and only if*

$$P^m \geqslant P_0 \equiv \frac{\Delta\theta\nu(2-\Delta\theta)}{2(1-\nu)}\,.$$

Proof. Solving (3.1) written with equality for P^m establishes the claim. □

That is, in the absence of communication between the agents the principal attains the first-best allocation provided she can impose a sufficiently high penalty on the agent who is found in breach of contract. Notice, in particular, that the penalty does not have to be very high. In fact, for $\nu < \nu_0$, where

$$\nu_0 = \frac{1}{1+\Delta\theta(2-\Delta\theta)} \geqslant \frac{1}{2},$$

the net payment to the agent is positive — i.e., the contract is accepted by the agent even if he has zero wealth and no access to borrowing: see Figure 3.1. It is also worth noting that, for a sizeable set of parameters where $P < P_0$, the principal cannot rule out tacit collusion and the first-best allocation is unattainable.

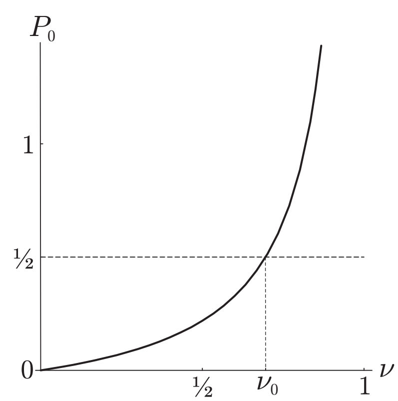

Figure 3.1: The value of P_0 as a function of ν for $\Delta\theta = 0.2$.

In other words, internal control can be very effective in preventing the agents from taking an inappropriate action, provided they find it sufficiently difficult to collude. Apart from the (somewhat unrealistic) setting where collusion is impossible owing to the lack of communication, the same result will obtain if with some probability $\gamma \in (0,1)$ any given agent is honest — i.e., refuses to collude even if doing so is profitable. Much as it is the case with communication, however, the principal will generally have a little influence over such an intrinsic personal quality as honesty; in fact, even the *ex ante* probability γ may be quite difficult to ascertain. This is one of the reasons to consider the avenues of increasing the value of internal control that are available to the principal; I do this in Chapter 4.

Two additional observations are in order. First, Proposition 4 shows that infinitely costly communication between the agents allows the principal to attain the first-best allocation at least for some values of the parameters, while with infinite transaction costs δ the agents still collude in the *hh*-case. In that sense, the agent's ability to communicate is costlier for the principal than their ability to exchange transfers. Second, in light of this observation, modeling the frictions of side contracting in reduced form as positive transaction costs results in underestimating the agents' cost of collusion. As a result, the model provides a conservative estimate of the value of internal control to the principal. As in Laffont and Meleu (1997), the non-linearity of transaction costs for $\delta > 0$ corresponds to the intuitive notion that it is easier to ask for a favor when one can offer something in return. The difference between the two models is that these authors assume the non-linearity while in my model it arises endogenously. Notice also that the results reported in Propositions 1–4 hold for $\delta = 0$, in which case transaction costs are linear. In Section 4.3, I dispense with exogenous transaction costs and consider an organizational arrangement that, under certain conditions, improves the principal's payoffs relative to the benchmark value of Π_0 defined in Section 3.2.

3.2 Contracting with Both Agents

In this section I relax the assumption that the principal is limited to offering contracts that are symmetric with respect to the agent's identity. Consider the full collusion region of parameters first. Since with $\alpha > 0$ in the *hl*- and *lh*-cases the efficient agent has to compensate his inefficient colleague for the extra effort given by $\psi(\cdot)$ for the side contract to be profitable, with positive transaction costs of collusion (i.e., with $\delta > 0$) the principal benefits by maximizing the amount to be transferred.[2] She can do this by offering the agents a contract specifying effort levels and transfers that, for the case where only one of them is efficient, satisfies the following incentive compatibility constraints:

$$t_{lh}^{A} - \frac{1}{2}\left(e_{lh}^{A}\right)^{2} \geqslant t_{ll}^{A} - \frac{1}{2}\left(e_{ll}^{A}\right)^{2} + \frac{1}{1+\delta}\Psi\left(e_{ll}^{B}\right) - \psi\left(e_{ll}^{A}\right), \tag{3.2}$$

$$t_{hl}^{B} - \frac{1}{2}\left(e_{hl}^{B}\right)^{2} \geqslant t_{ll}^{B} - \frac{1}{2}\left(e_{ll}^{B}\right)^{2} + \frac{1}{1+\delta}\Psi\left(e_{ll}^{A}\right) - \psi\left(e_{ll}^{B}\right), \tag{3.3}$$

provided that the acceptance constraints are not binding (these will be dealt with presently). It is easy to see that the grand contract satisfying constraints (3.2) and (3.3) is collusion proof in the *hl*- and *lh*-cases because the side contract cannot provide the inefficient agent (B and A, respectively), with a higher payoff; hence, by the standard assumption, he chooses the effort level preferred by the principal and his efficient colleague cannot collect any information rent.

Consider now the *hh*-case and assume, without loss of generality, that the principal offers to agent A a contract specifying the transfer that satisfies the following incentive compatibility constraint:

$$t_{hh}^{A} - \frac{1}{2}\left(e_{hh}^{A}\right)^{2} \geqslant t_{ll}^{A} - \frac{1}{2}\left(e_{ll}^{A}\right)^{2} + \Phi\left(e_{ll}^{A}\right) + \frac{1}{1+\delta}\Phi\left(e_{ll}^{B}\right). \tag{3.4}$$

At stage 6 agents report both their types and transfers spelled out in the grand contract. Again, agent A cannot gain by entering a side contract and agent B cannot deviate unilaterally; as a result, the grand contract is collusion proof. The acceptance constraints now take the following form:

$$\frac{1}{1+\delta}\Psi\left(e_{ll}^{B}\right) - \psi\left(e_{ll}^{A}\right) \geqslant 0, \tag{3.5}$$

$$\frac{1}{1+\delta}\Psi\left(e_{ll}^{A}\right) - \psi\left(e_{ll}^{B}\right) \geqslant 0. \tag{3.6}$$

It is shown in the appendix that (3.5) is always implied by (3.6). Finally, the participation constraints are given by

$$t_{jk}^{i} - \tfrac{1}{2}\left(e_{jk}^{i}\right)^{2} \geqslant 0\,, \tag{3.7}$$

[2]From now on, I will use the label *hl*-case to refer to the realization of the efficiency parameters when agent A only, and *lh*-case when agent B only, is efficient.

where $i = A, B$ and $j, k = h, l$.

The principal's problem, labeled C_3, is to choose e^i_{jk} and t^i_{jk} so as to maximize

$$\begin{aligned}\Pi_{C_3} = {} & \nu^2 \left(2\theta_h + e^A_{hh} - t^A_{hh} + e^B_{hh} - t^B_{hh}\right) \\ & + \nu (1-\nu) \left(\theta_h + \theta_l + e^A_{hl} - t^A_{hl} + e^B_{hl} - t^B_{hl}\right) \\ & + \nu (1-\nu) \left(\theta_h + \theta_l + e^A_{lh} - t^A_{lh} + e^B_{lh} - t^B_{lh}\right) \\ & + (1-\nu)^2 \left(2\theta_l + e^A_{ll} - t^A_{ll} + e^B_{ll} - t^B_{ll}\right) \\ & \text{subject to (3.2), (3.3), (3.4), (3.5), (3.6), and (3.7).}\end{aligned} \tag{3.8}$$

As shown in the Appendix, under contract C_3 there are three regions of parameters that determine the type of the solution (see Figure 3.2): in addition to the Full Collusion (FC) region where the agents collude in all but the *ll*-case and the Partial Collusion (PC) region where they collude only in the *hh*-case, for sufficiently high values of δ there now exists one more region, labeled Partial Collusion I (PCI), where collusion takes place in *hh*- and *hl*-cases. The solution to (3.8) is given in the following lemma.

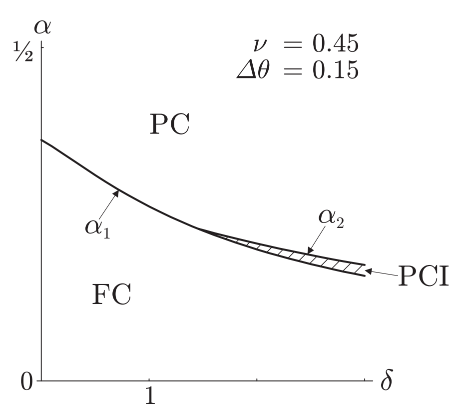

Figure 3.2: Three regions characterizing the solution to (3.8).

Lemma 2. *Under the optimal collusion-proof contract C_3:*

1. *The effort levels are given by:*

$$e^i_{hh} = e^i_{hl} = e^i_{lh} = 1 = e_{fb}\,, \text{ where } i = A, B\,;$$

(a) *In the Full Collusion (FC) region:*

$$e_{ll}^A = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2} \frac{1 - 2\alpha - \delta\left(\alpha - \nu(1-\alpha)\right)}{(1-2\alpha)(1+\delta)} \,,$$
$$e_{ll}^B = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2} \frac{1 - 2\alpha - \delta\alpha(1-\nu)}{(1-2\alpha)(1+\delta)} \,.$$

(b) *In the Partial Collusion (PC) region:*

$$e_{ll}^A = 1 - \Delta\theta \frac{\nu^2}{(1-\nu)^2} \,,$$
$$e_{ll}^B = 1 - \Delta\theta \frac{\nu^2}{(1-\nu)^2} \frac{1}{1+\delta} \,.$$

(c) *In the Partial Collusion I (PCI) region:*

$$e_{ll}^A = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2} \frac{(1-\alpha)\nu - \alpha}{(1-2\alpha)(1+\delta)} \,,$$
$$e_{ll}^B = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2} \frac{1 - \alpha(1+\nu)}{(1-2\alpha)(1+\delta)} \,.$$

2. *The FC region is characterized by* $\alpha \leqslant \alpha_1$ *and the PC region is characterized by* $\alpha > \max\{\alpha_1, \alpha_2\}$*, where*

$$\alpha_1 = \frac{(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left(\delta + 3\delta\nu^2 + (1-\nu)^2\right) - \sqrt{M_1}}{4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left[(2+\delta)(1+\delta+2\nu) + \nu^2\left(2 - \delta(\delta-3)\right)\right]} \,,$$

$$\begin{aligned} M_1 = {} & (1-\nu)^4(1+\delta)\left(\delta^2 + 4\Delta\theta(1+\delta)\right) \\ & - (\Delta\theta)^2(1+\delta)(1-\nu)\left[(1+\delta)^2 + \nu(1-\nu)(1-\delta^2) - \nu^3(1-\delta)(1+3\delta)\right] \,, \end{aligned}$$

$$\alpha_2 = \frac{(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left[1+\delta-2\delta\nu+\nu^2\left(3+\delta(3+\delta)\right)\right] - \sqrt{M_2}}{4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left[2+\delta(3+\delta)-2\delta\nu+\nu^2\left(6+\delta(7+3\delta)\right)\right]} \,,$$

and

$$\begin{aligned} M_2 = {} & \left[(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left(1+\delta-2\delta\nu+\nu^2\left(3+\delta(3+\delta)\right)\right)\right]^2 \\ & + \left[2(1+\delta)(1-\nu)^2 - \Delta\theta\left(1+\delta(1-\nu)^2+\nu^2\right)\right] \times \\ & \times \left[4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left(2+\delta(3+\delta)-2\delta\nu+\nu^2\left(6+\delta(7+3\delta)\right)\right)\right] \,. \end{aligned}$$

Proof. See Appendix. □

The regions that obtain with an asymmetric contract closely resemble the ones under a symmetric contract derived in Proposition 1. In fact, tt is easy to check that $\alpha_0|_{\delta=0} = \alpha_1|_{\delta=0}$, hence in the absence of transaction costs contracts C_1 and C_3 result in identical allocations. For future reference, I will denote by Π_0 the principal's expected payoff under both contracts with $\delta = 0$. Clearly, with positive transaction costs of collusion δ the principal benefits from treating the agents asymmetrically, i.e., $\Pi_{C_3} - \Pi_{C_1} > 0$.

From the viewpoint of the human resources department, contract C_3 can be interpreted as promoting a randomly chosen agent to a position of a "senior agent." Notice that the promotion decision is made before his type is known.[3] Furthermore, it is only valuable to the promoted agent in the *hh*- and *hl*-cases where he collects positive information rent and his colleague collects none — but in the *hl*-case where he is efficient and his lower-level colleague is not, it is the latter who collects all information rent. As a result, this organizational arrangement appears rather peculiar because organizations where lower-level employees wield all bargaining power in negotiations with their higher-level colleagues are not very often observed in practice. I consider a more plausible setting in Section 4.2.

3.3 On the Choice of Productive Technology

In this section, I discuss the extent to which the results are sensitive to the properties of productive technology used in the model of internal control. Two important properties are that (i) the agents' cost functions are additive in the productivity parameters and (ii) the principal's value function is additive in both agents' outputs. I consider the effects of both of these modeling choices in turn.

[3]It will be shown in Chapter 4 that in the cases where the agents differ in their *ex ante* probability of being efficient, the optimal choice of the agent to be promoted is determined by the parameters of the model.

3.3.1 The Cost Function

Early papers in the collusion literature, such as Tirole (1986) and Felli (1990), studied models where the principal's value function is linear in the output, the agent's cost of effort function, $c(e)$, is convex, and the efficiency parameter enters the output function additively (i.e., the output is given by $x = \theta + e$). More recent models, such as Severinov (2005), instead consider settings where the principal's value function is concave, the agent's cost function is linear, and the efficiency parameter represents variable costs and thus is multiplicative. These three components may be used in various combinations: for example, in Lawarrée and Shin (2005) the value function is concave, the cost function is convex, and the efficiency parameter enters the agents' cost functions multiplicatively. For the most part, the choice of production function is determined by modeling convenience and is not critical for the results.

In my model, each agent's efficiency parameter enters his cost function (and, therefore, the production function) additively and thus represents a fixed benefit (or cost saving) that only pertains to the agent's own division. This formulation captures, in a tractable manner, the well-known fact that some characteristics of the production process are easier for employees to manipulate than others. To illustrate this idea, consider the example with design and production engineers introduced in Chapter 2. Suppose that the productivity parameter represents the design engineer's creativity, which affects his output but has no bearing on the output of the production engineer, while his effort determines the quality of the blueprints that he produces and thus has a direct effect on the output of both divisions. Production function (2.1) then implies that a creative (i.e., efficient) design engineer who puts in less effort will produce sloppy blueprints of an innovative design — which, based on the author's interactions with design engineers, is not at all an implausible scenario.

That is, using the productivity parameter additively provides a parsimonious setting that allows me to study internal control as an instrument that makes it more difficult for employees to take inappropriate actions. In other words, the way of modeling internal control adopted here captures its essential property: by making malfeasance more difficult, it reduces, albeit usually does not eliminate, the probability of it happening. Clearly, this cost function represents a limiting case where the agent's productivity parameter affects his division only. The same result, however, will hold in a more general setting where it affects the productivity of the second division as well, so long as the magnitude of the latter effect is not too high. At the expense of complicating the computations, the cost function can be also modified so that the productivity parameter enters multiplicatively (i.e., as a marginal cost). In that case, for internal control to have a bite, the productivity parameter again will have to have greater effect on the agent's own division than on his colleague's.

3.3.2 The Production Function

The additivity of production function (2.1) in both agents' effort levels together with a normalization of the corresponding weights that sum up to unity allows me to separate the role of productive interdependency as a form of internal control from its effect on productivity. Indeed, in this formulation the intensity of internal control α enters the principal's payoff only via its effect on the cost of collusion. This separability considerably simplifies comparisons across various organizational arrangements. In reality, however, interdependencies linking employees' efforts take different forms that usually include some multiplicative component. Team synergy, where the output of the team exceeds the sum of individual contributions, is a classic example of such a multiplicative interdependency: see Autrey (2005). To what extent will the results reported in this dissertation change in the presence of team synergy?

Consider the following variant of production function (2.1):

$$\begin{cases} x^A(e^A, e^B) = \theta^A + e^A + \frac{1}{2}\beta e^A e^B, \\ x^B(e^A, e^B) = \theta^B + e^B + \frac{1}{2}\beta e^A e^B, \end{cases} \tag{3.9}$$

where $\beta \in [0, 1)$ represents the degree of productive interdependency, which here takes the form of team synergy. Production function (3.9) captures the positive effect that agent i's effort has on the output of his colleague and thus fits the examples introduced above. The first-best effort levels are now given by $e_{fb} = \frac{1}{1-\beta}$ and the principal's payoff is increasing in β.

In the hh-case the agents who wish to deviate from the contract and collect information rents have to exert effort levels $\tilde{e}^i$, and $\tilde{e}^j$, where $i, j = A, B$ and $i \neq j$, satisfying the following conditions:

$$\begin{aligned} \Delta\theta + \tilde{e}^i + \frac{1}{2}\beta\tilde{e}^i\tilde{e}^j &= e^i_{ll} + \frac{1}{2}\beta e^i_{ll}e^j_{ll}, \\ \Delta\theta + \tilde{e}^j + \frac{1}{2}\beta\tilde{e}^i\tilde{e}^j &= e^j_{ll} + \frac{1}{2}\beta e^i_{ll}e^j_{ll} \end{aligned} \tag{3.10}$$

The solution to (3.10) is given by

$$\tilde{e}^i = \frac{\sqrt{\left(2 + \beta(e^i_{ll} + e^j_{ll})\right)^2 - 8\beta\Delta\theta} + \beta\left(e^i_{ll} - e^j_{ll}\right) - 2}{2\beta},$$

$$\tilde{e}^j = \frac{\sqrt{\left(2 + \beta(e^i_{ll} + e^j_{ll})\right)^2 - 8\beta\Delta\theta} - \beta\left(e^i_{ll} - e^j_{ll}\right) - 2}{2\beta}.$$

In a similar fashion, we find that in the *hl*-case, the new effort levels, $\hat{e}^i$ and $\hat{e}^j$, are given by

$$\hat{e}^i = \frac{\sqrt{4\beta e^j_{ll}\left(2 + \beta e^i_{ll}\right) + \left(\beta(\Delta\theta - e^i_{ll} + e^j_{ll}) - 2\right)^2} - \beta\left(\Delta\theta - e^i_{ll} + e^j_{ll}\right) - 2}{2\beta},$$

$$\hat{e}^j = \frac{\sqrt{4\beta e^j_{ll}\left(2 + \beta e^i_{ll}\right) + \left(\beta(\Delta\theta - e^i_{ll} + e^j_{ll}) - 2\right)^2} + \beta\left(\Delta\theta - e^i_{ll} + e^j_{ll}\right) - 2}{2\beta}.$$

Observe that $\lim_{\beta\to 0}\tilde{e}^i = e^i_{ll} - \Delta\theta$ and $\lim_{\beta\to 0}\hat{e}^i = e^i_{ll} - \Delta\theta$; hence the result reported in Proposition 1 holds for $\beta \to 0$. From the continuity of the principal's payoff and the agents' information rents in β it follows that the result also holds for sufficiently small β. It is likely that the other results will hold as well, at least for a subset of the parameters, but the characterization is considerably more complicated. Since the multiplicative formulation adds little insight to the explication of the properties of internal control, I do not pursue this avenue further.

3.4 Discussion

In this chapter, I show that the value of internal control depends critically on the frictions in side contracting between the agents (in particular, on their ability to communicate in a credible manner) and, to a certain extent, on the set of feasible contracts available to the principal. The analysis demonstrates that, so long as the principal's ability to influence the mutual dealings between the agents is limited, she can only do so much in increasing the value of internal control; in particular, she cannot get rid of collusion altogether. As shown in Section 3.2, the practice of rewarding employees who refuse to take part in collusion studied formally by Beck (1986), Jones (1996), and Jones and Griggs (forthcoming), among others, is only effective under some circumstances (i.e., in the absence of transaction costs) and only reduces, but does not eliminate, the loss from collusion. Sometimes the principal can take advantage of the frictions inherent in side contracting that exist because of its informal, and sometimes covert, nature. For example, Felli (1990) assumes that the agents can renege on their collusive agreement at any time, provided that neither of them has started acting according to the agreement, and shows that this contracting friction alone allows the principal to prevent collusion costlessly.

Relations among the employees constitute what is often referred to as *informal organization*, which is shaped, to a large extent, by societal norms and organizational culture. Although the principal is usually capable of changing the latter, as shown by, e.g., Hermalin, (2001) and the recent attention to setting the right "tone at the top" as a means of improving organizational performance, she has at best a very little influence over the former. On the other hand, it is the principal who determines the structure of the *formal organization*, which establishes the hierarchy of authority. It has been shown in the economics literature that, in the presence of asymmetric information, the internal organization of a firm, and, in particular, the degree of centralization, usually affects its performance (see, e.g., Baron and Besanko, 1992). The exact nature of the relationship between the organizational form and performance, however, is very context specific and sensitive to the specification of a model, including the type of production function (cf. the discussion above), information structure, and timing. I investigate the effect of a hierarchical structure on the value of internal control in the following chapter.

Chapter 4

Internal Controls and Hierarchical Structure

It is shown in Chapter 2 that internal control is inseparable from collusion: with internal control in place, the agents always desire to engage in collusion, at least for some realizations of the efficiency parameters. The principal will, therefore, be interested in minimizing the loss from collusion while maintaining the benefits of internal control. In particular, she may try to reduce the agents' benefit from collusion when they choose to engage in it or, ideally, prevent collusion from happening altogether. It is likely, however, that the principal will be constrained in her choice of actions to prevent the loss from collusion: for example, communication between the agents will be possible under all but the rarest of circumstances. In this chapter, I consider one instrument that is available to many principals in real-life settings: the choice of the hierarchical structure of the firm.

In many organizations the employees involved in an internal control relationship occupy different hierarchical levels. In a typical scenario, a decision is made by a lower-level employee and subsequently ratified by a superior. Somewhat surprisingly, the tables are often turned, as in the practice of subcertification where financial data are certified by a subordinate employee who provides the data: see Vance (2007). A similar practice was adopted in the Soviet Union where all financial documents required the signatures of both the managing director of an enterprise and the chief accountant, even though the latter reported directly to the former. Why does the principal invest a subordinate with a right to control his boss? And, more generally, why do internal controls so often involve bosses and subordinates rather than peers who, by virtue of proximity, are in a better position to observe each other's actions? In this chapter I argue that the practice can be explained by studying collusion, the inevitable by-product of internal control. In particular, I show that, under a wide range of conditions, the value of internal control is, indeed, increased when the principal appoints one of the agents to a supervisory position and delegates to him contracting with the lower-level agent. Interestingly, the principal often optimally chooses for that position the agent who is *less* likely to be efficient because, by doing so, she minimizes the information rent accruing to the supervisor.

At first blush, the notion that a subordinate controls his boss appears to be counterintuitive. For example, Carmichael (1970) takes it as given that an employee will not report irregularities involving his supervisor and concludes that a hierarchical relations between individuals involved in internal control *reduces* its value. To reconcile the apparent contradiction, I will point out the crucial difference between settings where the subordinate has an option to report the inappropriate actions of his boss — e.g., when he decides whether or not to blow the whistle to the higher-ups — and settings where the option of "doing nothing" is simply not present — e.g., when the subordinate has to co-sign a check that will not be accepted without his signature. Many internal controls used in practice do, indeed, fall into the latter category where, for a transaction to take place, both employees have to take part in it, as in opening a safe with two keys or separating the functions of planning and implementation. In fact, it can be argued that this interdependency of the employees' actions is the most important property of internal control.

The benefits of delegation have long been explained in terms of the costs of communication that are saved when decision-making is pushed down the hierarchical structure. In my model, the benefits have a different origin: delegation is valuable because it allows the principal to increase the cost of collusion. Intuitively, since it usually is more difficult to collude with one's superior than with a colleague, the principal benefits from appointing one of the employees to a supervisory position even if there are no technological reasons to do so. Creating a hierarchical structure makes it easier for the principal to play one agent against the other, i.e., to use the "divide and conquer" strategy known to generations of managers and politicians. On the other hand, the costs of delegation are usually explained in terms of loss of control — and this is precisely why internal control enhances the value of delegation. That is, both instruments are shown to be complementary; formally, the principal's expected payoff as a function of two organizational choices (whether or not to implement internal control and delegation) is supermodular for a large set of parameters.[1]

4.1 Related Literature

The potential value of delegation in mitigating the losses from collusion has been pointed out in several studies. Baliga and Sjöström (1998) and Macho-Stadler and Pérez-Castrillo (1998) investigate the properties of centralization and delegation in a moral hazard environment; Laffont and Martimort (1998) study a model with adverse selection in a setting similar to the one used in this dissertation. The technology considered in the latter paper involves two productive agents: agent A produces the quantity q^A of an intermediate good and agent B uses it to produce the quantity q^B of the final good.[2] This production function has the property that $q^A = q^B$ at the optimum: the outputs are perfect complements and, as noted by Severinov (2005), the stake for collusion between the productive agents does not exist (i.e., the agents do not have anything to gain by forming a coalition). To introduce the possibility of collusion, the authors assume that the principal cannot distinguish one agent from another; as a result, the contract is *anonymous* in the sense that it specifies transfers to the agents as a function of their aggregated reports. This restriction on the contract space is interpreted as representing the limits on communication that exist in real-life organizations.

The authors model a collusive agreement as a side contract that specifies a manipulation of the report of the agents' types sent to the principal and transfers between the agents. In a centralized setting, the side contract is superimposed on

[1] Supermodularity can be interpreted as a generalization of complementarity: see discussion and references on p. 71.

[2] A similar model with types having continuous distributions is also used in Baron and Besanko (1992) to study the optimal internal organization of a firm.

the grand contract with the principal, while in a decentralized setting it is subsumed by the "official" employment contract offered by the supervisor to the agent. The timing of the game is as follows:

1. The principal offers a contract to the supervisor.
2. The supervisor accepts the contract.
3. The supervisor offers a side contract to the agent.
4. The agent accepts the side contract and reports his type to the supervisor.
5. The supervisor reports both his and the agent's types to the principal according to the manipulation specified by side contract.
6. The output is produced and the transfers are enforced.

The result is that delegation is preferred to centralization only in the presence of limits on communication.

The focus of my study, however, is not on collusion *per se* but on internal control, which, in a centralized setting, creates a stake for collusion without any additional assumptions. Even though the value of delegation has been long studied by organizational theorists (see, e.g., Mookherjee, 2006 and Poitevin, 2000 for recent reviews), I am not aware of analytical studies investigating the role of delegation in improving the effectiveness of internal control. One of the results established in the literature is that the properties of the allocations attainable under delegation are sensitive to the timing of the game. When the Revelation Principle applies (which means, in particular, that there is no collusion), delegation is always weakly dominated by centralization. Melumad, Mookherjee, and Reichelstein (1995) have shown that the two organizational arrangements are equivalent if the principal (i) monitors the output produced by the supervisor and (ii) contracts with the supervisor before the latter contracts or communicates with the agent. In the delegated contracting arrangement that they label H_1, the principal monitors the output produced by each of the agents. The time line of the game is as follows:

1. The principal offers to the supervisor a contract that specifies his compensation as a function of his report on his type and both outputs.
2. The supervisor accepts the contract and sends to the principal the report about his own type.
3. The supervisor offers a contract to the agent.

4. The agent accepts the contract and sends a report on his type to the supervisor. Based on the report, the supervisor specifies the level of output that should be produced by the agent.
5. The supervisor chooses his level of output, both outputs are produced, and the transfers are made.

The principal does not observe the interaction between the supervisor and the agent. Further, the supervisor cannot renege on his contractual obligations after observing the agent's type. The above sequence of events restricts the set of possible deviations available to the supervisor because (i) his report cannot be contingent on the realization of the agent's type and (ii) only the interim, rather than *ex post*, participation constraint of the supervisor has to be satisfied; i.e., for some realizations of the agents' type the supervisor may receive negative transfers. As a result, the potential for the principal's benefit is maximized.

In an alternative organizational arrangement, labeled H_1' by the authors, the timing is modified so that the supervisor does not report his type to the principal at stage 2 and, instead, contracts with the agent first and later, at stage 5, reports to the principal both his own and the agent's types. In addition, the supervisor is allowed to quit after he learns the agent's type, thus his participation constraint has to hold *ex post*. This setting is similar to the one used in Laffont and Martimort (1998). The authors show that under H_1' the supervisor's information rent is at least weakly higher than under H_1. The papers studying the effect of organizational arrangement on productivity also include Melumad, Mookherjee, and Reichelstein (1992), McAfee and McMillan (1995), and Baldenius, Melumad, and Ziv (2002).

In practice, the choice of an organizational arrangement is determined by several institutional factors, including the properties of the productive technology, information structure, and tradition (or organizational inertia). The properties of the pool of potential job candidates and the requisite skill set also play an important role. As a result, it may be difficult or impossible to implement the theoretical recommendations made by managerial economists. In particular, the setting corresponding to the time line just described may be attainable at the divisional level, where a large segment of an organization is set up as a profit center and the division head is delegated considerable discretion in hiring decisions, but infeasible at a lower level where a supervisor plays a role in the hiring policy but contracting with employees is ultimately carried out by the central personnel office. Thus in what follows I will consider two contractual settings that differ by the degree to which personnel decisions are delegated to one of the agents.

The chapter proceeds as follows. In Section 4.2 I study the setting with positive transaction costs where the principal delegates to the supervisor contracting with the agent. The setting with zero transaction costs is considered in Section 4.3 where the principal contracts with the supervisor and solicits his report before the supervisor contracts with the agents. I discuss the value of direct communication between the agent and the principal in Section 4.4. Section 4.5 concludes.

4.2 The Value of Delegation in the Presence of Transaction Costs

4.2.1 The Model

In this chapter I study the same production function (2.1) used in Chapter 2 but enrich the set of contracts available to the principal. I focus on what I call the main property of internal control — that with it in place, the agents can profitably deviate from the grand contract only if they coordinate their efforts. Formally, for any given pair of realizations $\left(\theta^A, \theta^B\right)$, production function (2.1) is a one-to-one mapping x: $\mathbb{R}_+^2 \mapsto \mathbb{R}_+^2$ from the set of effort pairs $\left(e^A, e^B\right)$ into the set of division outputs $\left(x^A, x^B\right)$. That is, in contrast to the benchmark case with no internal control where the principal has to know both efficiency parameters θ^i to extract the agents' information rents, internal control allows her to attain the same end if she learns just one efficiency parameter. To take advantage of this property, the principal has to treat the agents asymmetrically, but exogenous factors such as organizational traditions or equal opportunity laws may prevent her from doing so (the case considered in Chapter 2). Indeed, asymmetric mechanisms of the kind proposed by Demski and Sappington (1984) where the principal, in effect, "bribes" one of the agents to "snitch" on his colleague(s) may not be feasible in many institutional environments where the agents value their reputation, as suggested by the uniformly unfavorable attitude toward finks across different cultures. That is, the approach taken in Chapter 2 can be seen as a reduced form of a more involved dynamic model where the agents' reputational concerns arise endogenously.

One way for the principal to avoid the constraint that both agents be treated symmetrically is to appoint one of them supervisor and delegate to him the authority to contract with the second agent, who is hereafter referred to as simply the agent. Based on what we know about organizations, it would be natural to expect that a supervisor will usually have more bargaining power than his subordinate in any negotiation, be it over an employment contract or a collusive agreement. The analysis below shows that, whenever the principal prefers delegation to the centralized setting studied in Chapter 2, she, indeed, structures her contract with the supervisor in such a way that the latter has all bargaining power in all his negotiations with the agent. The benefit of delegation thus stems from the ability it gives the principal to influence the outcome of the collusive agreement and thereby make collusion costlier for the employees as a group (i.e., easier for her to prevent). The downside of the delegation is its cost, which typically is brought about by the loss of control. In my model, the cost of delegation takes the form of the loss of flexibility in contracting with the agent. Proposition 5, however, demonstrates that, for a large set of parameters, the benefit outweighs the cost.

The game unfolds according to the following sequence:

0. The principal chooses α that will be implemented.
1. Nature chooses the type of each agent. Each agent learns only his type.
2. The principal proposes a grand contract to agent A (the supervisor). The supervisor accepts or refuses the contract. If he refuses, the game ends and all parties receive their reservation utility.
3. If he accepts the grand contract, the supervisor offers a (side) contract to agent B (the agent).
4. The agents accepts or refuses the contract offered by the supervisor. If he refuses, the game ends and all parties receive their reservation utility.
5. If the agent accepts the contract, he reports his type to the supervisor.
6. The supervisor reports to the principal the aggregated information according to the manipulation specified in his contract with the agent.
7. The supervisor and the agent simultaneously produce their outputs and transfers specified in respective contracts are made.

I assume that the principal implements internal control (i.e., $\alpha > 0$) and observes the outputs produced by both agents (in the sequel, I will refer to them collectively as employees). The principal does not interact with the agent directly but pays his compensation as determined by the contract with the supervisor. This structure appears to be descriptive of many real-life organizations where the payroll functions are centralized. I consider the case where the agent receives his transfer from the supervisor in Section 4.3. The grand contract specifies the output levels and transfer to both employees: $\{e^A_{jk},\, t^A_{jk},\, e^B_{jk},\, t^B_{jk}\}$, where the subscripts $j, k = h, l$ denote the types of agents A and B respectively.

4.2.2 Characterization

As noted before, with internal control in place the employees can collect information rents only if they coordinate their actions. In the absence of the side contract designer, the agents, therefore, have to disclose their types to each other if they want to collect any rents. Observe that the supervisor has nothing to lose by truthfully disclosing his type to the agent because the agent does not communicate with the principal. Furthermore, if the agent accepts the contract, he will infer the supervisor's type from the effort level required of him anyway. The contract offered to the agent thus closely parallels the side contract considered in Chapter 2 in that it specifies the manipulation of the report sent to the principal, ϕ, side transfers y^{im}, where $i, m = A, B$, $i \neq m$, and employees' effort levels, $\tilde{e}$, as a function of the supervisor's type and the agent's report:

$$\left\{\phi\left(\theta^A, \hat{\theta}^B\right),\, y^{im}\left(\theta^A, \hat{\theta}^B\right),\, \tilde{e}^i\left(\theta^A, \hat{\theta}^B\right)\right\},$$

where $\theta^A = \theta_h, \theta_l$ is the type of the supervisor and $\hat{\theta}$ is the report submitted by the agent. The same property of the production function with internal control assures that the agent cannot benefit by deviating from the side contract unilaterally and thus has no choice but to truthfully report his type to the supervisor whenever he accepts the contract, i.e., $\hat{\theta}^B = \theta^B$. As before, side transfers, y^{im}, are subject to transaction cost, δ, which in this section is assumed to be strictly positive.

In general, the outcome of the negotiations between the supervisor and the agent, which is conducted under symmetric information, will be a function of their relative bargaining power. The principal, however, can influence the negotiation by her choice of the grand contract. To see how she achieves her goal, consider the *hh*-case first and suppose that the supervisor threatens (the agent) to report both types truthfully and exert the first-best effort level. If this threat is credible, the agent will be willing to transfer to the supervisor the amount up to his information rent that he would collect if the supervisor reports θ_l^A, θ_l^B and the effort levels are e_{ll}^A, e_{ll}^B. To assure that the supervisor's threat is credible, the principal has to pay him more than he would obtain as a result of the collective deviation just described. In particular, if she pays the rent of $\Phi\left(e_{ll}^A\right)+\frac{1}{1+\delta}\Phi\left(e_{ll}^B\right)$, the supervisor is indifferent between the agent's proposal and exerting the first-best level of effort and, therefore, by the standard assumption, takes the action preferred by the principal. The outcome of the side-contracting negotiation given the principal's grand contract is, therefore, exactly the same as would obtain in a negotiation in the absence of the principal if the supervisor held all bargaining power.[3]

Notice, however, that the grand contract does not allow the principal to transfer all bargaining power to the agent since she does not contract with him directly. She would, indeed, have benefitted from doing so in the *hl*-case (i.e., the case where the supervisor is efficient and the agent is not) because when the inefficient agent holds all bargaining power negotiating with the efficient supervisor, the (transaction) cost of collusion is maximized. It is this loss of flexibility in contracting that was referred to in Subsection 4.2.1. The next-best alternative is, again, to give all bargaining power in the *hl*-case to the supervisor by promising to him the transfers that satisfy the following incentive compatibility constraints:

$$t_{hl}^A-\frac{1}{2}\left(e_{hl}^A\right)^2\geqslant t_{ll}^A-\frac{1}{2}\left(e_{ll}^A\right)^2+\Psi\left(e_{ll}^A\right)-(1+\delta)\psi\left(e_{ll}^B\right), \tag{4.1}$$

$$t_{lh}^A-\frac{1}{2}\left(e_{lh}^A\right)^2\geqslant t_{ll}^A-\frac{1}{2}\left(e_{ll}^A\right)^2+\frac{1}{1+\delta}\Psi\left(e_{ll}^B\right)-\psi\left(e_{ll}^A\right). \tag{4.2}$$

The corresponding acceptance constraints are

$$\Psi\left(e_{ll}^A\right)-(1+\delta)\psi\left(e_{ll}^B\right)\geqslant 0, \tag{4.3}$$

$$\frac{1}{1+\delta}\Psi\left(e_{ll}^B\right)-\psi\left(e_{ll}^A\right)\geqslant 0. \tag{4.4}$$

[3]With $\delta>0$, the principal clearly prefers to transfer *all* bargaining power to one of the agents, in this case, the supervisor.

In general, the bargaining power in the negotiation over an employment agreement will be determined by the properties of the economic environment such as asset specificity and demand for supervisors and agents. One can, therefore, simply assume, as do, e.g., Laffont and Martimort (1998), that all bargaining power resides with the supervisor owing to one of these reasons. It appears that, in many real-life settings where the supervisor possesses the skills required for production and there exists a competitive supply of agents such an assumption is, indeed, justified. In my model, however, this assumption is unnecessary because the same result obtains endogenously as a part of the optimal contract offered by the principal.

Since the supervisor submits his report to the principal after learning the type of the agent, a collusion-proof grand contract has to satisfy the incentive compatibility and participation constraints *ex post* — i.e., each employee has to receive at least his reservation utility of 0 in each of the four possible realizations of efficiency parameters. From the argument above it follows that the incentive compatibility constraint for the hh-case takes the following form:

$$t_{hh}^{A}-\frac{1}{2}\left(e_{hh}^{A}\right)^{2}\geqslant t_{ll}^{A}-\frac{1}{2}\left(e_{ll}^{A}\right)^{2}+\Phi\left(e_{ll}^{A}\right)+\frac{1}{1+\delta}\Phi\left(e_{ll}^{B}\right). \tag{4.5}$$

The supervisor's participation constraints are given by:

$$t_{jk}^{A}\geqslant\tfrac{1}{2}\left(e_{jk}^{A}\right)^{2}, \tag{4.6}$$

where $j,k=h,l$. Since the agent cannot deviate from the grand contract unless he cooperates with the supervisor, only the participation constraints (and not incentive compatibility constraints) have to be satisfied for the agent:

$$t_{jk}^{B}\geqslant\tfrac{1}{2}\left(e_{jk}^{B}\right)^{2}, \tag{4.7}$$

where $j,k=h,l$.

The principal's problem, labeled D_1 (for delegation), is to choose e_{jk}^{i} and t_{jk}^{i}, where $i = A, B$ and $j, k = h, l$, so as to maximize

$$\begin{aligned}
\Pi_{D_1} &= \nu^2 \left(2\theta_h + e^A_{hh} - t^A_{hh} + e^B_{hh} - t^B_{hh}\right) \\
&\quad + \nu\,(1-\nu)\left(\theta_h + \theta_l + e^A_{hl} - t^A_{hl} + e^B_{hl} - t^B_{hl}\right) \\
&\quad + \nu\,(1-\nu)\left(\theta_l + \theta_h + e^A_{lh} - t^A_{lh} + e^B_{lh} - t^B_{lh}\right) \\
&\quad + (1-\nu)^2\left(2\theta_l + e^A_{ll} - t^A_{ll} + e^B_{ll} - t^B_{ll}\right)
\end{aligned} \tag{4.8}$$

subject to (4.1)–(4.7).

The solution to problem (4.8) is given in the Appendix. It shows, in particular, that the effort levels in the full collusion region are given by

$$e^i_{hh} = e^i_{hl} = e^i_{lh} = 1 = e_{fb}\,,\ \text{where } i = A, B\,,$$

$$e^A_{ll} = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\,, \tag{4.9}$$

$$e^B_{ll} = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\left\{1 - \delta\,\frac{1+\alpha\big(\delta(1-\nu)-2\nu\big)}{(1-2\alpha)(1+\delta)}\right\}, \tag{4.10}$$

An inspection of (4.9) and (4.10) reveals that, with positive transaction costs δ, in the ll-case the agent's effort is always strictly higher than the supervisor's; in fact, when δ is sufficiently high, for some values of the parameters the agent's effort even exceeds the first-best level. In addition to productivity improvement, raising e^B_{ll} has two effects: it increases the information rent collected by the supervisor in the hh- and lh-cases but also increases the cost of collusion in these two and, in addition, in the hl-case. In other words, the benefit of delegation of the type studied in this section is in reducing the loss from collusion. Notice that, even though both employees are *ex ante* identical, in expectation the supervisor's effort is strictly lower, and the pay strictly higher, than the agent's.

The following Proposition characterizes the relevant properties of the resultant allocation.

Proposition 5. *The allocation attainable under the contract with delegation, D_1, has the following property:*

$$\frac{\partial}{\partial\delta}\left(\Pi_{D_1} - \Pi_{C_1}\right)\bigg|_{\delta=0} > 0.$$

Proof. See Appendix. □

That is, with positive transaction costs δ, delegation improves the principal's payoff, at least so long as δ is not too large. The exact characterization of the conditions under which delegation is useful for the principal turns out to be rather complicated; however, graphical analysis demonstrates that the principal benefits from centralization for a wide range of δ provided that the probability that an agent is efficient, ν, is not too low: see Figure 4.1. This is the case because the employees as a group, if they choose to collude, have to incur the highest transaction cost in the hh-case, which occurs with probability ν^2. As a result, the collusion-proof contract that maximizes transaction costs owing to delegation saves the principal more the higher the probability ν is.

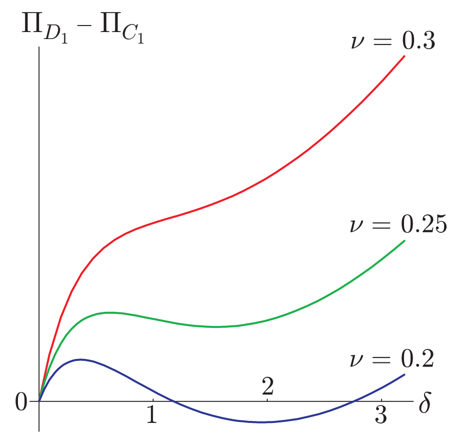

Figure 4.1: The sign of $\Pi_{D_1} - \Pi_{C_1}$ as a function of δ for different values of ν. In this example, $\Delta\theta = 0.3$ and $\alpha = 0.1$.

The result reported in Proposition 5 is consistent with the observation that it is easier for employees to collude with their peers than with superiors. Even though both types of collusion, which are often referred to as horizontal and vertical, respectively, are documented in the organizational literature, the latter type is likely to involve higher costs, including the costs of communication and enforcement of side contracts. For example, reputational concerns usually take different forms for managers and workers; as a result, some potentially profitable collusive agreements may not be self-enforcing. Transaction costs, which are taken as exogenous in this study, reflect these and similar contractual frictions.

4.2.3 The Choice of the Supervisor

In the model considered so far, the agents are assumed to be drawn from the same distribution and are *ex ante* identical; as a result, the supervisor can be chosen at random. I rule out the possibility that one of the agents is willing to pay the principal for the privilege of becoming a supervisor — but even if this is the case, the employees should again be treated symmetrically unless they have different willingness to pay for the supervisory position. However, the model allows me to study the principal's choice of a supervisor when the employees differ in some respect that relates to their productivity.

Consider the case where, as in the model introduced in Chapter 2, the employees' efficiency parameters are the same — say, owing to the technological environment — but the employees are now drawn from two populations that differ in the *ex ante* probability that any given employee is efficient. One can, for example, think of education (on-the-job training, certification, etc.) as an imperfect screening device that filters out some, but not all, agents with a low efficiency parameter. Formally, assume that agent A is efficient with probability $\nu \in (0, 1)$ and agent B is efficient with probability $\kappa\nu$, where $\kappa \geqslant 1$ and $\kappa\nu < 1$. As before, the two probabilities are uncorrelated. The model studied above can then be interpreted as a special case with $\kappa = 1$; I assume that $\kappa > 1$ in this subsection only. Denote by Π^i, $i = A, B$, the principal's expected payoff when agent i is appointed supervisor. The following result characterizes the principal's decision with respect to the appointment.

Proposition 6. *In the full collusion region, the principal's expected payoffs under contract D_1 have the following property:*

$$\Pi^A_{D_1} - \Pi^B_{D_1} > 0 \Leftrightarrow \Delta\theta < \min\{\Delta\theta_0, \Delta\theta_1\},$$

where $\Delta\theta_0$ is determined from Assumption 2 and $\Delta\theta_1$ is given by

$$\begin{aligned}
\Delta\theta_1 &= 2(1-2\alpha)(1+\delta)\big(1-\alpha(2+\delta)\big)(1-\nu)(1-\kappa\nu) \\
&\div \bigg| \Big[(1+\delta)\left(1+\alpha\big(\alpha(2+\delta)-2\big)\right) + \nu(1+\kappa)\left(1+\alpha\big(\alpha(2+\delta)(1+\delta+\delta^2)-2\big)\right) \\
&\qquad + \nu^2\kappa\left(1+\delta-\alpha\left(6+4\delta+\alpha(2+\delta)\big(\delta(3+2\delta)-1\big)\right)\right)\Big]\bigg|.
\end{aligned}$$

Proof. See Appendix. □

According to Proposition 6, the principal appoints to the supervisory position the agent who is *less* likely to be efficient if the difference in efficiency parameters, $\Delta\theta$, does not exceed a critical value given by $\Delta\theta_1$ (see Figure 4.2). The choice of the supervisor affects the principal's payoff via two channels: it affects (i) productivity because, in a generic case, the expected effort levels of the employees are different and (ii) the cost of collusion because the more likely it is that an inefficient supervisor is paired with an efficient agent, the higher the transaction cost of collusion and the easier it is for the principal to prevent it. The principal's choice is, therefore, determined by the relative magnitudes of these two effects: when the difference in productivity is not too high, the second effect dominates.

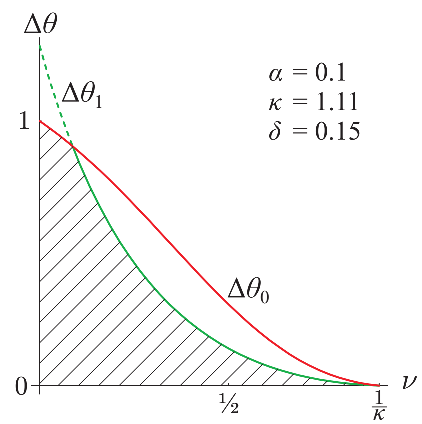

Figure 4.2: The region of parameters where $\Pi^A_{D_1} - \Pi^B_{D_1} > 0$.

The result reported in Proposition 6 is consistent with real-life settings where supervisors do not have to be particularly good at productive tasks, so long as they possess the requisite leadership qualities. For example, Sergei Korolyov, the Chief Designer of the Soviet space program, was admired for his leadership more than for his engineering prowess. A somewhat similar result is reported in Hart and Moore (2005), who show, in a different setting, that the agent's seniority in a hierarchy should always be inversely related to his probability of having a a useful idea. In contrast, my result demonstrates that the optimal appointment decision is contingent on the parameters of the model.

The model presented here highlights another reason for this somewhat counterintuitive finding. In my setting, the employee's willingness to collude is closely related to his type because the presence of at least one efficient employee is a necessary condition for collusion to occur. In that sense, the inefficient employee is "honest" — so long as his colleague is also inefficient. With positive transaction costs, however, appointing an inefficient employee to a position where he holds all bargaining power in the negotiations over the side contract is the next-best alternative to having a truly honest employee in that position. Proposition 6 shows that, if the difference in productivities is not too high, the employee who is least likely to take part in collusion (for whatever reason) should be appointed to the supervisory position. The result is consistent with the current debate over corporate governance where the "tone at the top" is one of the recurring themes but draws attention to the dependence of the optimal appointment decision on the organizational characteristics.

4.3 The Value of Sequential Contracting

As shown in the previous section, with positive transaction costs, δ, the principal can benefit from structuring the contractual arrangement with the agents in such a way as to maximize the cost of collusion. She attains this goal by treating the agents asymmetrically, subject to the constraints on the set of feasible contracts. It is, however, somewhat disconcerting that the results disappear in the absence of transaction costs: indeed, in this case, contract D_1 considered in the previous section provides no benefit over the symmetric contract C_1. The strongest argument against the assumption of positive transaction costs is not that collusive agreements in reality are frictionless, for they usually are not; rather, it is that transaction costs are taken as exogenous to the model. A more satisfying approach would be to either endogenize them, as does, e.g., Martimort (1997) in a model of repeated interaction, or consider a setting where the results hold for $\delta = 0$. In the remainder of the chapter, I take the second route.

The value of sequential contracting has been pointed out in the literature. In particular, Severinov (2005) shows, in a different model, that the timing considered in the previous section gives the supervisor the benefit of knowing the agent's type before submitting his report to the principal. Formally, in this case the participation and incentive compatibility constraints have to hold *ex post*, limiting the principal's ability to extract information rents from the employees. Can the principal do better if she solicits the supervisor's report before he contracts with the agent? As we shall see presently, the answer is yes, under certain conditions. The answer is, again, determined by the main property of internal control.

Recall that, with internal control in place, the supervisor costlessly learns the type of the agent and leaves him no information rent. It is, therefore, tempting to look for a solution where the principal contracts with the supervisor up front, pays him his information rent only, and extracts the agent's rent for free; better yet, if she could "sell" the firm to the first agent, the scope of collusion and, with it, both information rents would disappear altogether. It is safe to assume that the latter option is ruled out by the supervisor's limited wealth and various institutional constraints. The former option, however, could only be feasible if the supervisor credibly commits to exert the exact effort level required by the principal. In the absence of a commitment mechanism, the supervisor will have a strong incentive to deviate from his contractual effort level owing to the same main property of internal control, the flip side of which is that employees can produce any vector of outputs they want. In some anticipation, it should be noted that this latter property makes the characterization of incentive-compatible contracts with sequential contracting rather complicated and prevents me from giving a more definitive answer to the question posited above.

Before describing the game, I have to explain the role that delegation plays in this section. The main advantage of sequential contracting is that one of the employees — the supervisor — signs his contract before he has a chance to communicate with his colleague and cannot quit after the communication takes place.

This structure fits well with the settings where the agent is hired after the appointment of the supervisor. It is, however, unlikely that the principal could force both agents to sign their contracts before learning each other's types because this is only possible when both potential employees have already been identified and there will be a strong incentive for them to communicate. One way to interpret the model is, therefore, that delegation makes sequential contracting feasible — and it is the latter that proves to be valuable to the principal under a wide range of conditions. It is also worth noting that, by focusing on the setting where the supervisor holds all bargaining power and there are no frictions in side contracting, I give collusion its best chance at taking a bite off the principal's payoff.

4.3.1 The Model

The timing of the game is as follows:

0. The principal chooses α and $r(\cdot)$ that will be implemented.
1. Nature chooses the type of each agent. Each agent learns only his type.
2. The principal proposes a grand contract to agent A (the supervisor). The supervisor accepts or refuses the contract. If he refuses, the game ends and all parties receive their reservation utility.
3. If the supervisor accepts the grand contract, he reports his type to the principal.
4. The supervisor offers a contract to the agent. If he refuses, the game ends and all parties receive their reservation utility.
5. If the agent accepts the contract, he reports his type to the supervisor.
6. The supervisor reports the type of the agent to the principal.
7. The supervisor and the agent simultaneously produce their outputs and transfers specified in respective contracts are made.

The main difference between this time line and the one studied in Section 4.2 is that the supervisor reports his type *before* he learns the type of the agent; hence the reference to the *ex ante* participation constraint. As noted before, the agent does not collect any information rent because he cannot profitably deviate from the contract with the supervisor. Since the agent does not communicate with the principal, the supervisor reveals his type to the agent and offers him a menu consisting of two pairs of effort levels e_{jk}^{B} and transfers $t_{jk}^{B} = \frac{1}{2}\left(e_{jk}^{B}\right)^2$, where j is the type of the supervisor and $k = l, h$. There is no information asymmetry between the supervisor and the agent; hence the pair can be treated as a single productive unit. The Revelation Principle applies, and there is no loss of generality in considering grand contracts that represent direct revelation mechanisms. Denote by T_{jk} the transfers from the principal to the supervisor made under the grand contract. Formally, the grand contract is a triplet $\left\{e_{jk}^{A},\, e_{jk}^{B},\, T_{jk}\right\}$. That is, the principal pays the supervisor — and he, in turn, compensates the agent. One way to justify the assumption of zero transaction costs adopted in this section is that the side contract between the supervisor and the employee is subsumed by the "official" employment contract, which is enforced by the courts.

To save space, it is convenient to denote by U_{jk} the transfers net of corresponding production costs, or net transfers: $U_{jk} = T_{jk} - \frac{1}{2}\left(e_{jk}^{A}\right)^2 - \frac{1}{2}\left(e_{jk}^{B}\right)^2$. With this notation, the *interim* participation constraints, one for each type of the supervisor, take the following form:

$$\nu U_{lh} + (1-\nu)U_{ll} \geqslant 0 \quad \text{if } \theta^A = \theta_l\,, \tag{4.11}$$

$$\nu U_{hh} + (1-\nu)U_{hl} \geqslant 0 \quad \text{if } \theta^A = \theta_h\,. \tag{4.12}$$

Since only *ex ante* participation constraints have to be satisfied, the principal can set the transfers in such a way that, for some realizations of the efficiency parameters, the net transfers U_{jk} are negative.

Incentive compatibility constraints are determined by the deviations available to the supervisor. In general, there are two types of deviations. First, he can misrepresent his type at stage 3 and then at stage 5 either misrepresent the agent's type or report it truthfully. Alternatively, he can report his type truthfully and only misrepresent the agent's type at stage 5. Since the production function allows the productive unit headed by the supervisor to produce any pair of outputs required by the principal by choosing the effort levels appropriately, all possible deviations are feasible. In addition, one also has to consider the *inverse* incentive compatibility constraints that arise because, if the net transfer is negative, the supervisor is sometimes better off claiming that one of the employees is *more* efficient than is the case. One difficulty inherent in characterizing any incentive-compatible contract in this setting is that the constraints interact and there is no way to rule out any of them *a priori*.

There are many contracts that satisfy (4.11), (4.12), and the set of incentive compatibility constraints. Since my goal is to find a contract that outperforms the one derived under a centralized arrangement, I cannot simply take the effort levels that are optimal in the benchmark setting and check whether these can be induced by the new contract. My goal in this section, therefore, is to give an example of a contract, which I label D_2, that is feasible and incentive compatible and characterize the conditions under which it is preferred to the benchmark contract that guarantees the principal the payoff of Π_0 defined on p. 44 in Section 3.2.

4.3.2 Characterization

Consider first the case where the supervisor is inefficient and assume that he has truthfully reported this fact to the principal at stage 3; later I will check to see that he, indeed, does not benefit by misreporting his type. If he finds that the agent is efficient and misreports the agent's type, he can collect $\Psi\big(e_{ll}^{B}\big) - \psi\big(e_{ll}^{A}\big)$. Since, as shown above, this expression is always nonnegative, the incentive compatibility constraint is given by

$$U_{lh} \geqslant U_{ll} + \Psi\big(e_{ll}^{B}\big) - \psi\big(e_{ll}^{A}\big)\,. \tag{4.13}$$

Clearly, it will be satisfied with equality at the optimum. Solving (4.11) and (4.13) written with equality yields the following pair of transfers:

$$U_{lh} = (1-\nu)\left(\Psi\big(e_{ll}^{B}\big) - \psi\big(e_{ll}^{A}\big)\right) \geqslant 0\,, \tag{4.14}$$

$$U_{ll} = -\nu\left(\Psi\big(e_{ll}^{B}\big) - \psi\big(e_{ll}^{A}\big)\right) \leqslant 0\,. \tag{4.15}$$

Depending on the combination of binding incentive compatibility constraints, the principal may choose some other pair of transfers, in which case at least one of (4.11) and (4.13) will not be binding. In what follows, I assume that transfers (4.14) and (4.15) are a part of D_2 and characterize the conditions under which the contract is incentive compatible.

Consider next the case where the supervisor draws the high realization of his productivity parameter. He can claim to be inefficient at stage 3 and later report that the agent's type is either high or low. I will assume that, whenever the efficient supervisor misreports his type to the principal, he always reports at stage 5 that the agent is inefficient (i.e., that the binding constraints are *hh–ll* and *hl–ll*) and later characterize the conditions under which this deviation is the most profitable for the supervisor (i.e., that constraints *hh–lh* and *hl–lh* are slack). Intuitively, this will be the case when U_{ll} is not too low — i.e., when both ν and α are not too high. The grand contract, therefore, has to satisfy (with equality) the following incentive compatibility constraints:

$$U_{hh} \geqslant U_{ll} + \Phi\big(e^A_{ll}\big) + \Phi\big(e^B_{ll}\big), \tag{4.16}$$

$$U_{hl} \geqslant U_{ll} + \Psi\big(e^A_{ll}\big) - \psi\big(e^B_{ll}\big), \tag{4.17}$$

where U_{ll} is given by (4.15).

The conditions under which the remaining incentive compatibility constraints and the participation constraint for an efficient supervisor, (4.12), are not binding are given in the proof of Proposition 7 in the Appendix. The effort levels under contract D_2 are:

$$e^i_{hh} = e^i_{hl} = e^i_{lh} = 1 = e_{fb}\,,\ \text{where } i = A, B\,,$$

$$e^A_{ll} = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2}\,\frac{1-\alpha}{1-2\alpha}, \tag{4.18}$$

$$e^B_{ll} = 1 + \Delta\theta \frac{\nu}{(1-\nu)^2}\,\frac{\alpha}{1-2\alpha}. \tag{4.19}$$

As in contract D_1, the effort level required of the agent the *ll*-case is always higher than that required of the supervisor; furthermore, the agent's effort exerted in this case always exceeds the first-best level of 1. The relevant properties of the contract are summarized below.

Proposition 7. *The following two properties hold for contract D_2:*

1. *It is incentive compatible if and only if $(\alpha,\,\nu,\,\Delta\theta) \in \mathcal{S} \subset \mathbb{R}^3_+$. The set $\mathcal{S}$ is defined as follows:*

$$\mathcal{S} = \big\{\,\alpha,\,\nu,\,\Delta\theta \mid \alpha > 0,\, \nu \leqslant \min\{\nu_{ic1},\,\nu_{ic_2}\}\,,\, \Delta\theta \leqslant \Delta\theta^{\Psi}\big\}\ ,$$

where

$$\Delta\theta^{\Psi} = \frac{2(1-2\alpha)^2(1-\nu)^2}{\left(1-2\alpha(1-\alpha)\right)(1+\nu^2)},$$

$$\nu_{ic1} = \frac{1+2\alpha(1-\alpha) - \sqrt{1+4\alpha\big(1+\alpha\left(3\alpha(2-\alpha)-4\right)\big)}}{4\alpha(1-\alpha)},$$

$$\nu_{ic2} = \frac{1-3\alpha(1-\alpha) - \sqrt{\alpha(1-\alpha)\big(2-7\alpha(1-\alpha)\big)}}{(1-2\alpha)^2}.$$

2. *Whenever contract D_2 is incentive compatible, it outperforms the benchmark contract with $\delta = 0$. That is, $\Pi_{D_2} - \Pi_0 > 0$.*

Proof. See Appendix. □

According to Proposition 7, two incentive compatibility constraints and one acceptance constraint determine the shape of the region of parameters where contract D_2 is incentive compatible. The $(hh \to lh)$ incentive compatibility constraint, represented by ν_{ic1} in Figure 4.3, becomes binding when the supervisor in the *hh*-case benefits from claiming the *lh*-case and changing both efforts accordingly (instead of claiming the *ll*-case, as he does under contract D_2). The reverse incentive compatibility constraint $(hl \to hh)$, which is represented by ν_{ic2}, becomes binding when the efficient supervisor who has drawn an inefficient agent (the *hl*-case) benefits from claiming that the agent is efficient (*hh*-case) and adjusting the effort levels. Both of these constraints are brought about by the *ex ante* nature of the participation constraints, which, combined with risk neutrality of the employees, allow the principal to pay the supervisor negative net transfers when the agent turns out to be inefficient. The acceptance constraint is the only one of the three that depends on $\Delta\theta$: it shifts to the left as $\Delta\theta$ increases, and the incentive-compatibility region (the hatched area in Figure 4.3) shrinks. The acceptance constraint is closely related to the interim participation constraint for the efficient supervisor given by (4.12).

When the principal implements contract D_2, she distorts the effort levels in the *ll*-case only and requires the first-best effort levels in the remaining three cases. Figure 4.3 shows that she does it when the probability ν takes relatively low values — and, as a result, the effort distortions are not too high. Outside of the region

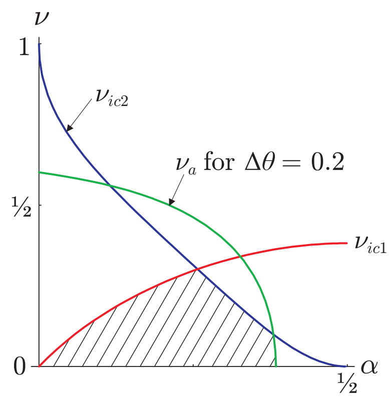

Figure 4.3: The hatched region represents the set $\mathcal{S}$ defined in Proposition 7. The variable ν_a solves the acceptance constraint (A.45) written with equality.

characterized in Proposition 7, the principal will likely distort the effort levels in some of the remaining three states as well. In particular, when an inverse incentive compatibility constraint is binding, the principal may choose to distort the effort levels in one of the "efficient" states — for example, in the *hh*-state if the constraint ($hl \to hh$) is binding — or to adjust the transfers in one of the "less efficient" states other than *ll*. In this case, the benefit from delegation may be reduced but it will likely remain positive for at least some values of the parameters.

The following corollary follows immediately from Proposition 7.

Corollary 2. $(\alpha,\, \nu,\, \Delta\theta) \in \mathcal{S} \Rightarrow \dfrac{\partial}{\partial \alpha}\Pi_{D_2} > 0\,.$

Proof. See Appendix. $\square$

As before, whenever the parameters of the model belong to set $\mathcal{S}$ and the principal chooses to implement internal control, she sets $\alpha = \overline{\alpha}$. The principal's choice of the organizational form is binary; I will use an indicator variable $\eta \in \{0, 1\}$ to denote her choice with respect to the organizational form, with $\eta = 1$ ($\eta = 0$) corresponding to the case where delegation is (is not) implemented. The principal's expected payoff can then be written as a function of two variables, one continuous and one discrete: $\Pi = \Pi(\alpha, \eta)$.[4] With this notation, the preceding analysis can be succinctly summarized as follows.

Proposition 8. *Suppose that* $(\alpha,\, \nu,\, \Delta\theta) \in \mathcal{S}$*. Then* $\Pi\,(\alpha, \eta)$ *is supermodular.*

Proof. By Proposition 5 in Severinov (2005), we have $\Pi(0,0) = \Pi(0,1)$. Proposition 7 implies that $\Pi(\alpha,1) > \Pi(\alpha,0)$ $\forall \alpha \in \mathcal{S}$. After rearranging, we obtain

$$\Pi(\alpha,1) - \Pi(0,1) > \Pi(\alpha,0) - \Pi(0,0) \quad \forall \alpha \in \mathcal{S},$$

which establishes the claim. $\square$

Supermodularity as a generalization of the Edgeworth's notion of complementarity was introduced in Topkis (1978) and further developed by Milgrom and Roberts (1990a, 1990b, 1995), among others.[5] In this setting, the principal's choice of the organizational form is represented by a binary set, hence the definition of complementarity involving positive mixed-partial derivatives cannot be applied. Since the choice set is linearly ordered, supermodularity is the appropriate notion. Stated informally, the main result of this chapter is that internal control and hierarchical structure involving delegation are complementary instruments for two different types of delegation and a wide range of parameters: see Figure 4.4.[6] Notice that the analysis above ignores potential benefits of delegation stemming from the costs of communication that it allows saving. As shown in the literature on delegation, such cost saving can be substantial, in which case the benefit of delegation will be even higher.

The mechanism that brings about the results reported in this section is distinct from the one that is at work in Section 4.2. Here, by using sequential contracting, the principal compels the supervisor to internalize the benefit of internal control — but only to a certain extent: as shown in the proof of Proposition 7, an efficient supervisor's always receives strictly positive expected information rent. In other

[4] It follows from Corollary 2 that the principal's decision to implement internal control can also be represented by a binary variable.

[5] See also Topkis (1998) for a book-length explication of supermodularity.

[6] As shown in Chapter 3, in the presence of transaction costs a hierarchical structure that does not involve delegation improves the principal's payoff even more than the one that does.

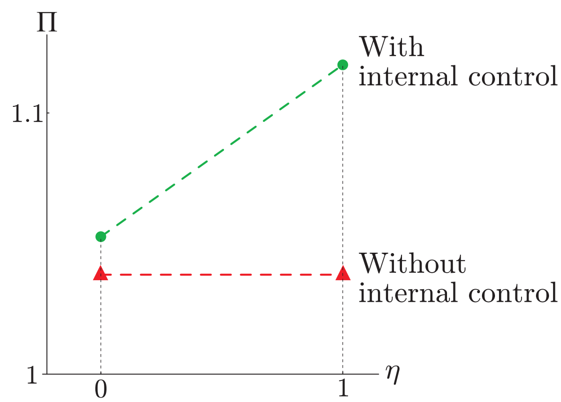

Figure 4.4: The supermodularity of internal control and hierarchical structure. The parameters are: $\alpha = 0.1$, $\nu = 0.35$, $\Delta\theta = 0.25$, $\theta_l = 0$.

words, contract D_2 falls short of outright "selling" the business to the supervisor, since the principal's payoff depends on the realizations of both efficiency parameters, and the resultant allocation falls short of the first best. Notice also that, by the continuity of the principal's payoff in δ, the ranking of the contracts reported in Proposition 7 also holds in the presence of transaction costs for sufficiently small δ.

4.3.3 The Choice of the Supervisor

In parallel with Subsection 4.2.3, consider now the principal's choice of the supervisor in the case where the *ex ante* probabilities that the agents are efficient differ slightly.[7] As before, assume, without loss of generality, that employee A is efficient with probability ν and employee B is efficient with probability $\kappa\nu$, where $\kappa > 1$ and $\kappa\nu < 1$. Denote by $\Pi^i_{D_2}$ the principal's payoffs under contracts D^i_2, where employee $i = A, B$ is appointed supervisor. The following result holds:

Proposition 9. *Suppose the parameters of the model belong to the set where contracts* D^A_2 *and* D^B_2 *are both incentive compatible. Then*

$$\Pi^A_{D_2} - \Pi^B_{D_2} > 0 \iff \Delta\theta < \frac{2(1-2\alpha)^2(1-\nu)(1-\kappa\nu)}{(1-2\alpha(1-\alpha))\,(1+\kappa\nu^2)}.$$

[7] The assumption that the difference is small allows me to appeal to the continuity of constraints and, by so doing, sidestep the arduous process of checking them one by one.

Proof. See Appendix. □

That is, whenever the principal implements contract D_2, she almost always appoints the employee who is less likely to be efficient to the supervisory position so long as the difference in efficiency is not too high. This result is consistent with the one reported in Proposition 6 and is even more straightforward to explain in the setting with sequential contracting: as noted above, an efficient supervisor collects positive information rent in expectation while an efficient agent does not. Appointing the employee who is less likely to be efficient to the supervisory position, therefore, allows the principal to reduce the amount of information rent that he will collect (with probability $\kappa\nu$) if he turns out to be efficient.

4.4 On the Value of Vertical Communication

In the previous sections it was assumed that the agent cannot communicate with the principal directly. Although such lack of communication is descriptive of many companies where the top executives are usually quite difficult to get access to, it stands in apparent contradiction to the recent trend, promoted in part by SOX, of establishing "hot lines" or communication channels allowing the employees to "blow the whistle" to a higher authority about the (alleged) misconduct of their superiors. Whistleblowing has long attracted the attention of researchers in management (see, e.g., Near and Miceli, 1996), law (see, e.g., Callahan, Dworkin, Fort, and Schipani, 2002), and, more recently, economics. Analytical studies of whistleblowing in the economics tradition include Friebel and Raith (2004), who show that allowing the agent to "snitch" on an unproductive supervisor can provides incentives for the latter to hire unproductive agents, and Ting (2007), who presents a model of a public agency and demonstrates that allowing whistleblowing can undermine the supervisor's ability to discipline the agent.

The question that arises in the setting studied in this chapter is, can the principal benefit from allowing the agent to communicate with her directly? Consider delegation with sequential contracting and suppose that the agent can credibly communicate the type of the supervisor, which he learns in the course of negotiation over his contract, to the principal. This ability will benefit the agent since he will have more bargaining power in his negotiation with the supervisor and receive some information rent — but, with zero transaction costs, the total cost to the principal of making the contract incentive compatible will remain the same. In other words, the agent's ability to communicate "over the head" of his supervisor benefits the agent but not the principal. This observation is consistent with reports that unscrupulous employees do, indeed, abuse whistleblowing: see, e.g., Geller (2004).

Under what conditions would the principal be worse off by establishing a communication channel required by SOX? She will stand to lose if, for example, the receipt of a complaint from an employee triggers a costly investigation. Note that, since the contract is incentive compatible, the supervisor has already truthfully reported his type to the principal, so the agent does not have any new information to convey. It is also likely that in real-life settings the agent who informs higher-ups and observes no response will be compelled to blow the whistle externally — usually to the authorities or the press — in which case the principal will bear some costs. Finally, the agent's ability to use a threat of communicating with the principal and extract higher payments from the supervisor will sometimes force the latter do demand a higher pay. I leave the investigation of these settings for future research.

4.5 Discussion

In this chapter, I consider several avenues of increasing the value of internal control available to the principal. I show that she can eliminate the scope for collusion completely only if she "sells" the business to one of the employees, in which case the latter fully internalizes the benefits of internal control and the first-best allocation obtains. In organizational arrangements that fall short of this most radical one, the scope for collusion always remains, at least for one realization of the efficiency parameters (the hh-case). In the presence of transaction costs of collusion, the principal benefits from contracting with both employees and treating them asymmetrically. In organizational settings where employees occupying identical positions have to be treated equally for exogenous reasons, the principal, for a wide range of parameters, benefits by appointing one of the employees to a supervisory position. Promoting one of the employees also makes possible sequential contracting where the supervisor has to report his type to the principal before he hires the agent. Under some conditions, such a hierarchical structure increases the value of internal control even in the absence of transaction costs of collusion. When one of the agents is more likely than the other to be efficient *ex ante*, for a wide range of parameters the principal optimally promotes the agent who is less likely to be efficient because doing so reduces the loss from collusion.

The main property of internal control that is behind the results reported in this chapter is that, with it in place, the employees can take advantage of the information asymmetry at the principal's expense only if they coordinate their actions. In effect, the principal creates a hierarchical structure, with or without delegation, to play one of the agents against the other by writing the contract with the supervisor in such a way that he has all bargaining power in his negotiation with the agent over their collusive agreement that is subsumed by the "official" employment contract. In the model considered in Section 4.2, giving one of the employees all bargaining power in negotiating with his colleague maximizes the expected transaction cost of collusion, thus making collusion easier to prevent. As shown in Section 3.2, in the absence of restrictions on the contract form, the principal can do better by contracting with both agents, although in this case she still "promotes" one of them and in effect again creates a hierarchical arrangement.

The model studied in Section 4.3 does not depend on the presence of (exogenous) transaction costs: in it, the benefit of creating a hierarchical structure is brought about by the combination of employees' risk neutrality and the principal's ability to contract with the supervisor before he learns the type of the agent — i.e., before the agent is hired (hence the term sequential contracting). The analysis demonstrates that the main property of internal control — that, with it, the agents have to collude if they want to collect information rents — cuts both ways because the employees' ability to produce any output levels they like limits the principal's ability to take full advantage of sequential contracting. In particular, when the intensity of internal control α is sufficiently high, the employees may claim that at least one of them is *more* efficient than is the case. Nonetheless, she benefits from delegation with sequential contracting for some values of parameters. In fact, the latter organizational arrangement beats simultaneous contracting with both agents when transaction costs are sufficiently low.

The results reported in this chapter contribute to the literature on delegation by focusing on its property that so far has been, to a large degree, overlooked by researchers: its ability to increase the value of internal control. It is not a mere coincidence that the two phenomena work so well together. To see this, notice that the value of the main property of internal control described above to the principal stems from the ability that it gives her to learn the efficiency parameter of one employee as soon as she learns the efficiency parameters of his colleague. That is, the principal can control the lower-level employee, at least to a certain extent, without interacting with him directly. We know from the delegation literature that the loss of control is the main cost of delegation; internal control is valuable in this setting precisely because it allows the principal to obtain the benefit of delegation while limiting its cost. In other words, internal control and delegation are shown to be complementary instruments. The model thus helps explain why one of the employees involved in internal control so often directly reports to the other. An immediate corollary that follows from the above results is that, even though the principal may delegate contracting with the agent to the supervisor, she always reads the report provided by the internal control system herself. The practice, where the internal audit department usually reports directly to the board, bears out this prediction of the model. It is also reassuring that the results reported in this chapter obtain under two different types of delegation and thus appear to be robust to alternative specifications.

Chapter 5

Conclusion

One property of internal control, one of the oldest instruments in the managerial toolbox, is that implementing it creates the possibility of collusion among employees. In this dissertation, I use the principal–agent framework to explicate this property and investigate the effect of internal control on the welfare of shareholders (represented by the principal) and employees (represented by the agents). I show that, when the agents find it relatively easy to collude, implementing internal control decreases agency welfare, harming the principal and the agents viewed as a group, but, in the presence of positive transaction costs of collusion, increases productive efficiency. When this is the case, the principal, under certain conditions, can increase her expected payoff by using internal control as a threat instead of actually implementing it. If the available technology does not allow the principal to completely eliminate productive interdependency, which makes internal control possible, she sometimes benefits from reducing the accuracy of the accounting information system, which is an integral part of the internal control system.

The analysis demonstrates that, unless the principal can substantially increase the cost of communication between the agents or "sell" the business to one of them, eliminating collusion is infeasible — yet, for a large set of parameters, the benefit from implementing internal control outweighs the loss from collusion. Since in real-life settings the principal's ability to affect mutual dealings among employees is at best limited and liquidity constraints usually render the "sell-out" solution impossible, internal control virtually always operates under the shadow of collusion. It turns out, however, that one instrument available to the principal — the choice of organizational form — can be very effective in minimizing the loss from collusion and thus maximizing the value of internal control.

In particular, the principal benefits from creating a hierarchical structure, even if there is no technological reason to do so. I study two different versions of the model corresponding to the settings with and without transaction costs of collusion and show that appointing one of the agents supervisor and delegating to him the task of contracting with the lower-level agent increases the value of internal control for a wide range of parameters. Even though the mechanisms behind the results in the two settings are distinct, the intuition is similar in both cases: by creating a hierarchy, the principal compels the supervisor to internalize, if only partially, the value of internal control. As a result, two instruments of corporate governance — internal control and delegation — are shown to be complementary in many situations. The model also demonstrates that, when one of the agents is more likely to be efficient *ex ante* than the other, in most circumstances appointing to the supervisory position the one who is less likely to be efficient reduces the principal's loss from collusion.

At least to some extent, the results reported here are sensitive to the modeling choices made to keep the model tractable. A simple productive technology that is additive in the agents' outputs captures the essential feature of many internal controls and, especially, the segregation of duties, which makes the agents' outputs interdependent so that no inappropriate action can be taken by any agent unilaterally. The additive production technology considerably simplifies comparisons across various regimes and, as argued in Chapter 3, modifying it to include a multiplicative element representing team synergy does not appear to alter the qualitative nature of the results. The formulation adopted in this dissertation is sufficiently general and, in particular, does not require that the agents' actions and outputs be similar.

For simplicity, I normalize the coefficients in productive function (2.1) so that the interdependencies are symmetric in both directions and assume that production takes place simultaneously. A natural extension of the model would consider a setting where production is sequential (as, e.g., in Baliga and Sjöström, 1998) and, as a result, the interdependency is asymmetric because the agent who is the last to take his action can adjust his effort knowing the action of the colleague. Likewise, the model can be extended by considering a continuous distribution of types.

Since the probability of both agents having the same type is zero in this case, the agents will have to exchange transfers with probability one and the characteristics of the contract will depend on expected transfers, which will be determined by the properties of the distribution. The model can also be easily extended to the case of $n > 2$ agents, where the principal will choose different interdependency parameters so that the output is informative about the identity of the deviating agent. Finally, one can open the "black box" and study an extensive-form model of bargaining between the agents. Insofar as the principal, in real-life settings, is capable of affecting the bargaining process, this extension appears to be a promising avenue for future research.

$\star \quad \star \quad \star$

Appendix

Proof of Lemma 1

Since transfers to the agents in the ll-case, t_{ll}, only enter participation constraint (2.12), the principal can reduce them without affecting any other constrains, hence $t_{ll} = \frac{1}{2}\left(e_{ll}\right)^2$. Next, observe that $\Phi'(e) = \Delta\theta > 0$, hence incentive compatibility constraint (2.13) is always binding at the optimum. The type of compensation scheme offered by the principal will be determined by the sign of $\mathcal{R}(e_{ll})$ defined by (2.17):

$$\begin{aligned}\mathcal{R}(e_{ll}) &= \Psi(e_{ll}) - (1+\delta)\psi(e_{ll}) \\ &= e_{ll}\Delta\theta\frac{1-2\alpha-\alpha\delta}{1-2\alpha} - (\Delta\theta)^2\frac{1-2\alpha(1-\alpha)+\alpha^2\delta}{2(1-2\alpha)},\end{aligned}$$

where $e_{ll} = e_{ll}\left(\alpha, \delta, \Delta\theta, \nu\right)$. Since

$$\frac{\partial}{\partial\alpha}\mathcal{R}(e_{ll}) = -\Delta\theta\frac{\Delta\theta(1+\alpha\delta) + e_{ll}\delta(1-2\alpha)}{(1-2\alpha)^3} < 0,$$

$\mathcal{R}(e_{ll})$ is decreasing in α monotonically. Denote by $\alpha_0 = \alpha_0(\delta, \Delta\theta, \nu)$ the solution to $\mathcal{R}(e_{ll}) = 0$. Next, we have

$$\mathcal{R}(e_{ll})|_{\alpha=0} = \tfrac{1}{2}\Delta\theta(2e_{ll} - \Delta\theta) > 0,$$

where the inequality follows by Assumption 2. Therefore, $\alpha_0 > 0$, and the FC region is characterized by $\alpha \in (0, \alpha_0)$. With $\alpha > \alpha_0$, the agents collude only in the hh-case. I will consider both regions in turn.

i. Full Collusion Region.

In the FC region, $\mathcal{R}\big(e_{ll}\big) > 0$. First, observe that

$$\mathcal{R}'(e) = \Delta\theta\left(1 - \frac{\alpha\delta}{1-2\alpha}\right),$$

which is positive for $\alpha < \frac{1}{2+\delta}$. Letting α_1 denote the solution to $\mathcal{R}(e) = 0$, we find that

$$\alpha_0 - \alpha_1 = \frac{\sqrt{e^2\delta^2 + \Delta\theta(4e - \Delta\theta)(1+\delta)} - e\delta}{(4e - \Delta\theta)(2+\delta)} > 0,$$

where the inequality follows by Assumption 2. That is, for $\alpha \leqslant \alpha_0$, $\mathcal{R}'(e) > 0$ and therefore incentive compatibility constraints (2.19) and (2.20) are binding at the optimum. Substituting binding incentive compatibility and participation constraints in the principal's problem, we can rewrite it as follows:

$$\begin{aligned} \max_{e_{jk}} \Pi_C^{FC} &= 2\nu^2\left(\theta_h + e_{hh} - \tfrac{1}{2}(e_{hh})^2 - \Phi(e_{ll})\right) \\ &+ 2\nu(1-\nu)\Big(\theta_h + e_{hl} - \tfrac{1}{2}(e_{hl})^2 + \theta_l + e_{lh} - \tfrac{1}{2}(e_{lh})^2 - \tfrac{2}{2+\delta}\mathcal{R}(e_{ll})\Big) \\ &+ 2(1-\nu)2\left(\theta_l + e_{ll}\right), \end{aligned} \tag{A.1}$$

where $j,k = A,B$. The solution to (A.1) is given by

$$e_{hh} = e_{hl} = e_{lh} = 1 = e_{fb}, \tag{A.2}$$

$$e_{ll} = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\left(1 - \frac{\delta(1-\nu)}{(2+\delta)(1-2\alpha)}\right). \tag{A.3}$$

Denote by α_0 the smaller of the two solutions to $\mathcal{R}\left(e_{ll}\right)$, where e_{ll} is given by (A.3):

$$\alpha_0 = \frac{(4+\delta)(1-\nu)^2 - \Delta\theta\left(1 + 2\nu(1+\delta) + \nu^2(1-\delta)\right) - \sqrt{M}}{(2+\delta)\left(4(1-\nu)^2 - \Delta\theta\big(1 + \nu\left(2 + \nu + 2\delta(1-\nu)\right)\big)\right)},$$

where

$$\begin{aligned} M &= \Big((4+\delta)(1-\nu)^2 - \Delta\theta\big(1 + 2\nu(1+\delta) + \nu^2(1-\delta)\big)\Big)^2 \\ &- (2+\delta)\left((2-\Delta\theta)(1+\nu^2) - 4\nu\right)\left(4(1-\nu)^2 - \Delta\theta\left(1 + \nu\big(2 + \nu + 2\delta(1-\nu)\big)\right)\right). \end{aligned}$$

The full collusion region is characterized by $\alpha \leqslant \alpha_0$.

ii. Partial Collusion Region.

In the PC region, $\mathcal{R}(e_{ll}) < 0$: the agents do not collude in the hl-case and the principal's problem takes the following form:

$$\begin{aligned}\max_{e_{jk}} \Pi_C^{PC} &= 2\nu^2 \left(\theta_h + e_{hh} - \tfrac{1}{2}(e_{hh})^2 - \Phi(e_{ll})\right) \\ &+ 2\nu(1-\nu)\left(\theta_h + e_{hl} - \tfrac{1}{2}(e_{hl})^2 + \theta_l + e_{lh} - \tfrac{1}{2}(e_{lh})^2\right) \\ &+ 2(1-\nu)2\left(\theta_l + e_{ll}\right),\end{aligned} \tag{A.4}$$

The solution to (A.4) is given by

$$\begin{aligned}&e_{hh} = e_{hl} = e_{lh} = 1 = e_{fb}, \\ &e_{ll} = 1 - \Delta\theta\frac{\nu^2}{(1-\nu)^2}.\end{aligned} \tag{A.5}$$

Given that the objective function is (weakly) concave and the constraint set is convex, the proposition is proved. □

Proof of Proposition 1

i. Full Collusion Region.

Productive efficiency is given by

$$E_{C_1}^{FC} = 2\nu^2 e_{hh} + 2\nu(1-\nu)\left(e_{hl} + e_{lh}\right) + 2(1-\nu)^2 e_{ll}.$$

Substituting the values from (A.2), (A.3) and (2.8) and simplifying, we obtain

$$E_{C_1}^{FC} - E_{NC} = 2\delta\nu\Delta\theta\frac{1-\nu}{(2+\delta)(1-2\alpha)} \geqslant 0,$$

with strict inequality for $\delta > 0$.

To evaluate the principal's expected payoff, consider first the case of $\delta = 0$. Substituting the effort levels given by (A.2) and (A.3) into the principal's objective function (A.1) and simplifying yields

$$\begin{aligned}\Pi^{FC}_{C_1}\big|_{\delta=0} - \Pi_{NC} &= \frac{(\Delta\theta)^2\nu}{(1-2\alpha)^2(1-\nu)^2}\left[\nu^2 + 2\alpha(1-\alpha)\left(1-\nu(3-\nu(1-\nu))\right)\right] \\ &> \frac{(\Delta\theta)^2(1-2\alpha)\nu}{2(1-\nu)^2} > 0\,,\end{aligned}$$

where the first inequality follows from $\alpha < \frac{1}{2}$ and Π_{NC} is given by (2.9). Since in the FC region the principal's expected payoff with internal control, $\Pi^{FC}_{C_1}$, is clearly increasing in δ while Π_{NC} is not a function of δ, we have $\Pi^{FC}_{C_1} - \Pi_{NC} > 0$ for all $\delta \geqslant 0$.

Since both agents supply the first-best levels of effort in the *hh*- and *hl*-cases, agency welfare under the contract C_1 is given by

$$\begin{aligned}W^{FC}_{C_1} &= \nu^2\left(2\theta_h + 1\right) + 2\nu(1-\nu)\left(\theta_l + \theta_h + 1\right) \\ &\quad + 2(1-\nu)^2\left(\theta_l + e_{ll} - \tfrac{1}{2}\left(e_{ll}\right)^2\right).\end{aligned}$$

After substituting the value of e_{ll} given by (A.3) and simplifying, we obtain

$$W^{FC}_{C_1} - W_{NC} = \frac{(\Delta\theta)^2\nu^2}{(1-\nu)^2}\left((1-\nu) - \frac{(2-2\alpha(2+\delta)+\delta\nu)^2}{(1-2\alpha)^2(2+\delta)^2}\right), \tag{A.6}$$

where W_{NC} is given by (2.11).

Solving $W^{FC}_{C_1} - W_{NC} = 0$ for α yields

$$\alpha^{\star}_{C_1} = \frac{4\nu + 2\delta\nu(3+\nu) - \delta(2+\delta)\left(\sqrt{(1-\nu)^3}+1\right)}{2\nu(2+\delta)^2}.$$

Hence $W^{FC}_{C_1} - W_{NC} > 0 \Leftrightarrow \alpha > \alpha^{\star}_{C_1}$.

ii. Partial Collusion Region.

Substituting the values from (A.5) and (2.8) and simplifying, we obtain

$$E^{PC}_{C_1} - E_{NC} = 2\nu(1-\nu)\Delta\theta > 0\,.$$

Substituting (A.5) into the principal's objective function (A.4) and simplifying yields

$$\begin{aligned}\Pi^{FC}_{C_1} - \Pi_{NC} &= \frac{\Delta\theta\nu}{(1-\nu)^2}\,\left[2(1-\nu)^3 + \Delta\theta\left(2\nu(1-\nu(1-\nu)) - 1\right)\right] \\ &> \frac{\Delta\theta\nu}{1-\nu}\,\left[1 - 2\nu(1-\nu^2)\right] > 0\,,\end{aligned}$$

where the first inequality follows from Assumption 2 and Π_{NC} is given by (2.9).

After substituting the value of e_{ll} given by (A.5) into the expression for agency welfare and simplifying, we obtain

$$W^{PC}_{C_1} - W_{NC} = (\Delta\theta)^2\nu^2\frac{1-\nu-\nu^2}{(1-\nu)^2},$$

which is positive for $\nu < \frac{1}{2}\left(\sqrt{5}-1\right) \approx 0.618$. □

Proof of Corollary 1

Substituting the effort levels given by (A.2) and (A.3) in the principal's objective function (A.1) and simplifying, we obtain:

$$\begin{aligned}\frac{\partial}{\partial\alpha}\Pi^{FC}_{C_1} &= \frac{4\Delta\theta\nu}{(1-2\alpha)^3(2+\delta)^2(1-\nu)}\times \\ &\times\left(\delta(1-2\alpha)(2+\delta)(1-\nu)^2 + \Delta\theta\left[(2+\delta)(1+\alpha\delta)(1+\nu^2) - 4\nu(1+\delta) - \delta^2\nu^2\right]\right).\end{aligned}$$

From Assumption 2 and (A.3) it follows that

$$\Delta\theta \leqslant \frac{(1-2\alpha)(2+\delta)(1-\nu)^2}{\left(1-\alpha(1+\nu^2)\right)(2+\delta) - 2\nu(1-\nu)(1+\delta)}. \tag{A.7}$$

By (A.7), we can write:

$$\frac{\partial}{\partial \alpha}\Pi_{C_1}^{FC} \geqslant \frac{4\nu(1+\delta)(2+\delta)(1-\nu)^5}{(1-2\alpha)\left[(2+\delta)\left(1-\alpha(1+\nu^2)\right)-2\nu(1-\nu)(1+\delta)\right]^2} > 0,$$

where the second inequality follows because $\Delta\theta > 0$ and hence the denominator in (A.7) is strictly positive. $\square$

Proof of Proposition 2

The agents' expected rent can be found as $R_{C_1} = W_{C_1} - \Pi_{C_1}$. After simplification, we obtain:

$$\begin{aligned} R_{NC} - R_{C_1}^{FC}\big|_{\delta=0} &= \frac{2\nu(\Delta\theta)^2}{(1-2\alpha)^2(1-\nu)^2}\left[\nu^2 + \alpha(1-\alpha)\left(1-3\nu-\nu^2-\nu^3\right)\right] \\ &> \frac{\nu(\Delta\theta)^2(1-\nu)}{2(1-2\alpha)^2} > 0, \end{aligned}$$

where the first inequality follows from $\alpha < \frac{1}{2}$. Since $R_{C_1}^{FC}$ is decreasing in δ, we have $R_{NC} - R_{C_1}^{FC} > 0$ for all $\delta \geqslant 0$.

In a similar fashion, we obtain

$$\begin{aligned} R_{NC} - R_{C_1}^{PC} &= \frac{\nu\Delta\theta}{(1-\nu)^2}\left[2(1-\nu)^3 - \Delta\theta\left(1-\nu+\nu^2-3\nu^3\right)\right] \\ &\geqslant \frac{\nu(1-\nu)^2}{\left((1-\nu)^2+\nu^2\right)^2}\left[1-5\nu+7\nu^2-\nu^3\right] > 0, \end{aligned}$$

where the first inequality holds because it follows from (A.5) and Assumption 2 that

$$\Delta\theta \leqslant \frac{(1-\nu)^2}{(1-\nu)^2+\nu^2}.$$

We have shown that $R_{NC} - R_{C_1} > 0$, hence the agents (as a group) will always be willing to pay the principal up to the amount given by $R_{NC} - R_{C_1}$. Notice that, by Proposition 1, the principal's threat to implement internal control is credible. If the principal accepts their offer, her payoff is given by

$$\Pi_{C_2} = \Pi_{NC} + R_{NC} - R_{C_1} = W_{NC} - R_{C_1}\,.$$

If she rejects the offer, her payoff is $\Pi_{C_1} = W_{C_1} - R_{C_1}$. Hence $W_{NC} > W_{C_1}$ implies $\Pi_{C_2} > \Pi_{C_1}$. $\square$

Proof of Proposition 3

Suppose that $\underline{\alpha} > 0$ and the following condition holds:

$$W_{NC} - W_{C_1}^{FC} - \underline{\alpha}(\Delta\theta)^2\left(\underline{\alpha}(1-\nu) + 2\nu\right) > 0\,. \tag{A.8}$$

To see that there exists a set with non-empty interior for which condition (A.8) holds, observe that for $\delta = 0$, it is equivalent to $\underline{\alpha} < \tilde{\alpha}$, where

$$\tilde{\alpha} = \frac{\nu}{1-\nu}\,\frac{1-\sqrt{1-\nu}}{\sqrt{1-\nu}} > 0$$

and $W_{C_1}^{FC} - W_{NC}$ is given by (A.6). Since $W_{C_1}^{FC}$ is continuous in δ, condition (A.8) will also hold for sufficiently small $\delta > 0$.

Consider two reporting functions:

$$r_0(x) = x\,;$$
$$r_1(x) = \begin{cases} \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} & \text{if } x \in \left[\theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} - \hat{\alpha}\Delta\theta,\, \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} + \hat{\alpha}\Delta\theta\right], \\ x & \text{otherwise} \end{cases}$$

for some $\hat{\alpha} \geqslant \underline{\alpha} > 0$. We have $m(r_1) = \hat{\alpha}\Delta\theta > 0 = m(r_0)$. Since $W_{NC} - W_{C_1}^{FC} > 0$, the principal prefers to offer contract C_2. Under contract NC, the effort levels required of the efficient and inefficient agents, e_h and e_l, are given by (2.7):

$$e_h = 1\,, \quad e_l = 1 - \Delta\theta\frac{\nu}{1-\nu}\,.$$

Suppose that the principal sets $\alpha = \hat{\alpha}$. In the hl-case, when the efficient agent

i claims to be inefficient and exerts the effort of $e_l - \Delta\theta$, the levels of output will be

$$x^i = \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} + \hat{\alpha}\Delta\theta,$$
$$x^j = \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu} - \hat{\alpha}\Delta\theta,$$

where $i, j = A, B$ and $i \neq j$. With reporting function r_1, instead of x^i and x^j given above, the principal observes, for both agents, $x = \theta_l + 1 - \Delta\theta\frac{\nu}{1-\nu}$, the levels of output required of inefficient agents. Furthermore, the agents cannot reduce their effort levels without being detected. In the ll-case, however, the agents can reduce their effort levels from e_l to $e_l - \hat{\alpha}\Delta\theta$ without being detected, and the principal compensates them only for these lower effort levels. For the same reason, information rents collected by the efficient agents in the hh-case are given by $\Phi(e_l - \hat{\alpha}\Delta\theta)$. Notice that reporting function r_1 does not distort output levels when the agents exert e_h.

Agency welfare with reporting function r_1 is given by

$$\begin{aligned} W(r_1) &= 2\nu\left(\theta_h + e_h - \tfrac{1}{2}(e_h)^2\right) \\ &\quad + 2(1-\nu)\left(\theta_l + (e_l - \hat{\alpha}\Delta\theta) - \tfrac{1}{2}(e_l - \hat{\alpha}\Delta\theta)^2\right) \\ &= W_{NC} - \hat{\alpha}(\Delta\theta)^2\left(\hat{\alpha}(1-\nu) + 2\nu\right) . \end{aligned}$$

Next, we have

$$\begin{aligned} \Pi_{C_2}(r_1) &= \Pi_{NC}(r_1) + R_{NC} - R_{C_1} \\ &= 2\nu\left(\theta_h + e_h - \tfrac{1}{2}(e_h)^2 - \Phi(e_l - \hat{\alpha}\Delta\theta)\right) \\ &\quad + 2(1-\nu)\left(\theta_l + (e_l - \hat{\alpha}\Delta\theta) - \tfrac{1}{2}(e_l - \hat{\alpha}\Delta\theta)^2\right) + R_{NC} - R_{C_1}. \end{aligned}$$

Since R_{NC} and R_{C_1} do not depend on $\hat{\alpha}$, the following inequality holds:

$$\frac{\partial}{\partial\hat{\alpha}}\Pi_{C_2}(r_1) = -2\hat{\alpha}(\Delta\theta)^2(1-\nu) < 0.$$

That is, the principal implements $\hat{\alpha} = \underline{\alpha}$ but uses $\alpha = \overline{\alpha}$ in negotiating the agent't concession in exchange for not implementing internal control. By assumption, we have

$$W(r_1) - W_{C_1}^{FC} = W_{NC} - W_{C_1}^{FC} - \underline{\alpha}(\Delta\theta)^2\left(\underline{\alpha}(1-\nu) + 2\nu\right) > 0. \tag{A.9}$$

Hence, by Proposition 2, $\Pi(r_1) - \Pi(r_0) > 0$. □

Proof of Lemma 2

The problem has the following Lagrangian:

$$
\begin{aligned}
\mathcal{L} = \nu^2 & \left(2\theta_h + e^A_{hh} - t^A_{hh} + e^B_{hh} - t^B_{hh}\right) \\
& + \nu\,(1-\nu)\left(\theta_h + \theta_l + e^A_{hl} - t^A_{hl} + e^B_{hl} - t^B_{hl}\right) \\
& + \nu\,(1-\nu)\left(\theta_l + \theta_h + e^A_{lh} - t^A_{lh} + e^B_{lh} - t^B_{lh}\right) \\
& + (1-\nu)^2\left(2\theta_l + e^A_{ll} - t^A_{ll} + e^B_{ll} - t^B_{ll}\right) \\
& + \lambda_1\left(t^A_{hh} - \tfrac{1}{2}\big(e^A_{hh}\big)^2 - t^A_{ll} + \tfrac{1}{2}\big(e^A_{ll}\big)^2 - \Phi\big(e^A_{ll}\big) - \tfrac{1}{1+\delta}\Phi\big(e^B_{ll}\big)\right) \\
& + \lambda_2\left(t^B_{hl} - \tfrac{1}{2}\big(e^B_{hl}\big)^2 - t^B_{ll} + \tfrac{1}{2}\big(e^B_{ll}\big)^2 - \tfrac{1}{1+\delta}\Psi\big(e^A_{ll}\big) + \psi\big(e^B_{ll}\big)\right) \\
& + \lambda_3\left(t^A_{lh} - \tfrac{1}{2}\big(e^A_{lh}\big)^2 - t^A_{ll} + \tfrac{1}{2}\big(e^A_{ll}\big)^2 - \tfrac{1}{1+\delta}\Psi\big(e^B_{ll}\big) + \psi\big(e^A_{ll}\big)\right) \\
& + \mu_1\left(t^A_{hh} - \tfrac{1}{2}\big(e^A_{hh}\big)^2\right) + \mu_2\left(t^A_{hl} - \tfrac{1}{2}\big(e^A_{hl}\big)^2\right) \\
& + \mu_3\left(t^A_{lh} - \tfrac{1}{2}\big(e^A_{lh}\big)^2\right) + \mu_4\left(t^A_{ll} - \tfrac{1}{2}\big(e^A_{ll}\big)^2\right) \\
& + \mu_5\left(t^B_{hh} - \tfrac{1}{2}\big(e^B_{hh}\big)^2\right) + \mu_6\left(t^B_{hl} - \tfrac{1}{2}\big(e^B_{hl}\big)^2\right) \\
& + \mu_7\left(t^B_{lh} - \tfrac{1}{2}\big(e^B_{lh}\big)^2\right) + \mu_8\left(t^B_{ll} - \tfrac{1}{2}\big(e^B_{ll}\big)^2\right) \\
& + \xi_1\left(\tfrac{1}{1+\delta}\Psi\big(e^B_{ll}\big) - \psi\big(e^A_{ll}\big)\right) + \xi_2\left(\tfrac{1}{1+\delta}\Psi\big(e^A_{ll}\big) - \psi\big(e^B_{ll}\big)\right)
\end{aligned}
$$

with the additional nonnegativity constraints.

The Kuhn-Tucker conditions for e^A_{hh} and t^A_{hh} are

$$\frac{\partial\mathcal{L}}{\partial e^A_{hh}} = \nu^2 - e^A_{hh}\left(\lambda_1 + \mu_1\right) \leqslant 0\,, \quad e^A_{hh}\frac{\partial\mathcal{L}}{\partial e^A_{hh}} = 0\,, \tag{A.10}$$

$$\frac{\partial\mathcal{L}}{\partial t^A_{hh}} = -\nu^2 + \lambda_1 + \mu_1 \leqslant 0\,, \quad t^A_{hh}\frac{\partial\mathcal{L}}{\partial t^A_{hh}} = 0\,. \tag{A.11}$$

From (A.10), it follows that $e^A_{hh} > 0$. Participation constraint (3.7) then implies that $t^A_{hh} > 0$ and, therefore, by (A.11) $\lambda_1 + \mu_1 = \nu^2$. Thus $e^A_{hh} = 1$. It follows from Assumption 2 that $\Phi\big(e^A_{ll}\big) > 0$ and $\Phi\big(e^B_{ll}\big) > 0$, hence $t^A_{hh} > \frac{1}{2}(e^A_{hh})^2$ and thus $\mu_1 = 0$ and $\lambda_1 = \nu^2$. Proceeding in a similar fashion, we find that $e^B_{hh} = 1$ and $\mu_5 = \nu^2$.

There are four (potential) cases to consider, depending on the binding acceptance constraints (3.5) and (3.6).

Case 1 ($\xi_1 = 0, \xi_2 = 0$): Full Collusion

The Kuhn-Tucker conditions for e^A_{lh} and t^A_{lh} are

$$\frac{\partial \mathcal{L}}{\partial e^A_{lh}} = \nu(1-\nu) - e^A_{lh}\,(\lambda_3 + \mu_3) \leqslant 0\,, \quad e^A_{lh}\frac{\partial \mathcal{L}}{\partial e^A_{lh}} = 0\,, \tag{A.12}$$

$$\frac{\partial \mathcal{L}}{\partial t^A_{lh}} = -\nu(1-\nu) + \lambda_3 + \mu_3 \leqslant 0\,, \quad t^A_{lh}\frac{\partial \mathcal{L}}{\partial t^A_{lh}} = 0\,. \tag{A.13}$$

Since $\xi_1 = 0$, we have $\frac{1}{1+\delta}\Psi\big(e^B_{ll}\big) - \psi\big(e^A_{ll}\big) > 0$ and $t^A_{lh} > \frac{1}{2}(e^A_{lh})^2$, hence $\mu_3 = 0$. Then (A.12) and (A.13) imply that $\lambda_3 = \nu(1-\nu)$; thus $e^A_{lh} = 1$. In a similar fashion, we find that $\lambda_2 = \nu(1-\nu)$, $\mu_3 = \mu_6 = 0$, and $\mu_8 = 1-\nu$. To summarize, the agents' efforts in the *hl*- and *lh*-cases are given by

$$e^i_{hh} = e^i_{hl} = e^i_{lh} = 1, \tag{A.14}$$

where $i = A, B$.

Next, substituting the values of λ_1–λ_3 and simplifying, we can write the Kuhn-Tucker conditions for e^A_{ll} and t^A_{ll} as:

$$\frac{\partial \mathcal{L}}{\partial e^A_{ll}} = (1-\nu)^2 - \nu\Delta\theta\frac{1-2\alpha-\delta\,(\alpha-\nu(1-\alpha))}{(1-2\alpha)(1+\delta)} - e^A_{ll}\,(\mu_4 - \nu) \leqslant 0\,, \tag{A.15}$$

$$e^A_{ll}\frac{\partial \mathcal{L}}{\partial e^A_{ll}} = 0\,, \tag{A.16}$$

$$\frac{\partial \mathcal{L}}{\partial t^A_{ll}} = -1 + \nu(1-\nu) + \mu_4 \leqslant 0\,, \quad t^A_{ll}\frac{\partial \mathcal{L}}{\partial t^A_{ll}} = 0\,. \tag{A.17}$$

From (A.17) we have $\mu_4 = 1 - \nu(1-\nu)$. Also, from Assumption 2 we know that $e^A_{ll} > 0$, hence it follows from (A.16) that (A.16) holds with equality and, after simplification, we obtain:

$$e^A_{ll} = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\,\frac{1-2\alpha-\delta\,(\alpha-\nu(1-\alpha))}{(1-2\alpha)(1+\delta)}\,. \tag{A.18}$$

Following similar steps, we find that

$$e_{ll}^{B} = 1 - \Delta\theta \,\frac{\nu}{(1-\nu)^2}\,\frac{1-2\alpha-\delta\alpha(1-\nu)}{(1-2\alpha)(1+\delta)}\,. \tag{A.19}$$

Denote by α_1 the smaller of the two solutions to $\frac{1}{1+\delta}\Psi\big(e_{ll}^{A}\big) - \psi\big(e_{ll}^{B}\big) = 0$ with the effort levels (A.18) and (A.19); it is given by

$$\alpha_1 = \frac{(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left(\delta + 3\delta\nu^2 + (1-\nu)^2\right) - \sqrt{M_1}}{4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left[(2+\delta)(1+\delta+2\nu) + \nu^2\left(2-\delta(\delta-3)\right)\right]}\,,$$

where

$$\begin{aligned} M_1 = {} & (1-\nu)^4(1+\delta)\left(\delta^2 + 4\Delta\theta(1+\delta)\right) \\ & - (\Delta\theta)^2(1+\delta)(1-\nu)\left[(1+\delta)^2 + \nu(1-\nu)(1-\delta^2) - \nu^3(1-\delta)(1+3\delta)\right]\,. \end{aligned}$$

The Full Collusion (FC) region is then characterized by $\alpha \leqslant \alpha_1$.

Case 2 ($\xi_1 > 0$**,** $\xi_2 = 0$)

From (A.18) and (A.19), we obtain

$$e_{ll}^{B} - e_{ll}^{A} = \Delta\theta\,\frac{\delta}{1+\delta}\,\frac{\nu^2}{(1-\nu)^2} \geqslant 0\,,$$

with strict inequality for $\delta > 0$; hence

$$\frac{1}{1+\delta}\Psi\big(e_{ll}^{B}\big) - \psi\big(e_{ll}^{A}\big) - \left[\frac{1}{1+\delta}\Psi\big(e_{ll}^{A}\big) - \psi\big(e_{ll}^{B}\big)\right] = \frac{\Delta\theta}{1+\delta}\,\frac{1+\alpha\delta}{1-2\alpha}\left(e_{ll}^{B} - e_{ll}^{A}\right) \geqslant 0.$$

That is, $\xi_2 = 0$ implies $\xi_1 = 0$ and, therefore, it cannot be the case that $\xi_1 > 0$ and $\xi_2 = 0$.

Case 3 ($\xi_1 = 0$**,** $\xi_2 > 0$)**: Partial Collusion I**

Now, constraint (3.6) is satisfied with equality and thus individual rationality constraint (3.3) takes the form of the corresponding incentive compatibility constraint,

$t^B_{hl} \geqslant \frac{1}{2}(e^B_{hl})^2$. The optimal effort levels e^A_{ll} and e^B_{ll} are given by:

$$e^A_{ll} = 1 - \Delta\theta \, \frac{\nu}{(1-\nu)^2} \, \frac{(1-\alpha)\nu - \alpha}{(1-2\alpha)(1+\delta)} \,, \tag{A.20}$$

$$e^B_{ll} = 1 - \Delta\theta \, \frac{\nu}{(1-\nu)^2} \, \frac{1-\alpha(1+\nu)}{(1-2\alpha)(1+\delta)} \,. \tag{A.21}$$

Denote by α_2 the smaller of the two solutions to $\frac{1}{1+\delta}\Psi\big(e^B_{ll}\big) - \psi\big(e^A_{ll}\big)$ where the effort levels are (A.20) and (A.21); it is given by

$$\alpha_2 = \frac{(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left[1+\delta-2\delta\nu+\nu^2\left(3+\delta(3+\delta)\right)\right] - \sqrt{M_2}}{4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left[2+\delta(3+\delta)-2\delta\nu+\nu^2\left(6+\delta(7+3\delta)\right)\right]} \,,$$

where

$$\begin{aligned} M_2 = &\left[(1+\delta)(4+\delta)(1-\nu)^2 - \Delta\theta\left(1+\delta-2\delta\nu+\nu^2\left(3+\delta(3+\delta)\right)\right)\right]^2 \\ &+ \left[2(1+\delta)(1-\nu)^2 - \Delta\theta\left(1+\delta(1-\nu)^2+\nu^2\right)\right] \times \\ &\quad \times \left[4(1+\delta)(2+\delta)(1-\nu)^2 - \Delta\theta\left(2+\delta(3+\delta)-2\delta\nu+\nu^2\left(6+\delta(7+3\delta)\right)\right)\right] \,. \end{aligned}$$

The Partial Collusion I (PC I) region is characterized by $\alpha_1 < \alpha \leqslant \alpha_2$.

Case 4 ($\xi_1 > 0, \xi_2 > 0$): Partial Collusion

The Partial Collusion (PC) region is characterized by $\alpha > \max\{\alpha_1, \alpha_2\}$. Now, both constraints (3.5) and (3.6) are satisfied with equality and can be replaced by the corresponding individual rationality constraints. The optimal effort levels e^A_{ll} and e^B_{ll} are given by:

$$e^A_{ll} = 1 - \Delta\theta \, \frac{\nu^2}{(1-\nu)^2} \,, \tag{A.22}$$

$$e^B_{ll} = 1 - \Delta\theta \, \frac{\nu^2}{(1-\nu)^2} \, \frac{1}{1+\delta} \,. \tag{A.23}$$

Since the objective function is (weakly) concave and the constraint set is convex, the Kuhn-Tucker conditions are sufficient as well as necessary. □

Solution to Problem D_1

The problem has the following Lagrangian:

$$
\begin{aligned}
\mathcal{L} = {} & \nu^2 \left(2\theta_h + e^A_{hh} - t^A_{hh} + e^B_{hh} - t^B_{hh}\right) \\
& + \nu\,(1-\nu) \left(\theta_h + \theta_l + e^A_{hl} - t^A_{hl} + e^B_{hl} - t^B_{hl}\right) \\
& + \nu\,(1-\nu) \left(\theta_l + \theta_h + e^A_{lh} - t^A_{lh} + e^B_{lh} - t^B_{lh}\right) \\
& + (1-\nu)^2 \left(2\theta_l + e^A_{ll} - t^A_{ll} + e^B_{ll} - t^B_{ll}\right) \\
& + \lambda_1 \left\{ t^A_{hh} - \tfrac{1}{2}\left(e^A_{hh}\right)^2 - t^A_{ll} + \tfrac{1}{2}\left(e^A_{ll}\right)^2 - \Phi\left(e^A_{ll}\right) - \tfrac{1}{1+\delta}\Phi\left(e^B_{ll}\right) \right\} \\
& + \lambda_2 \left\{ t^A_{hl} - \tfrac{1}{2}\left(e^A_{hl}\right)^2 - t^A_{ll} + \tfrac{1}{2}\left(e^A_{ll}\right)^2 - \Psi\left(e^A_{ll}\right) + (1+\delta)\psi\left(e^B_{ll}\right) \right\} \\
& + \lambda_3 \left\{ t^A_{lh} - \tfrac{1}{2}\left(e^A_{lh}\right)^2 - t^A_{ll} + \tfrac{1}{2}\left(e^A_{ll}\right)^2 - \tfrac{1}{1+\delta}\Psi\left(e^B_{ll}\right) + \psi\left(e^A_{ll}\right) \right\} \\
& + \mu_1 \left\{ t^A_{hh} - \tfrac{1}{2}\left(e^A_{hh}\right)^2 \right\} + \mu_2 \left\{ t^A_{hl} - \tfrac{1}{2}\left(e^A_{hl}\right)^2 \right\} \\
& + \mu_3 \left\{ t^A_{lh} - \tfrac{1}{2}\left(e^A_{lh}\right)^2 \right\} + \mu_4 \left\{ t^A_{ll} - \tfrac{1}{2}\left(e^A_{ll}\right)^2 \right\} \\
& + \mu_5 \left\{ t^B_{hh} - \tfrac{1}{2}\left(e^B_{hh}\right)^2 \right\} + \mu_6 \left\{ t^B_{hl} - \tfrac{1}{2}\left(e^B_{hl}\right)^2 \right\} \\
& + \mu_7 \left\{ t^B_{lh} - \tfrac{1}{2}\left(e^B_{lh}\right)^2 \right\} + \mu_8 \left\{ t^B_{ll} - \tfrac{1}{2}\left(e^B_{ll}\right)^2 \right\} \\
& + \xi_1 \left\{ \Psi\left(e^A_{ll}\right) - (1+\delta)\psi\left(e^B_{ll}\right) \right\} + \xi_2 \left\{ \tfrac{1}{1+\delta}\Psi\left(e^B_{ll}\right) - \psi\left(e^A_{ll}\right) \right\}
\end{aligned}
$$

with the additional nonnegativity constraints.

The Kuhn-Tucker conditions for e^A_{hh} and t^A_{hh} are

$$
\frac{\partial \mathcal{L}}{\partial e^A_{hh}} = \nu^2 - e^A_{hh}\left(\lambda_1 + \mu_1\right) \leqslant 0\,, \quad e^A_{hh}\frac{\partial \mathcal{L}}{\partial e^A_{hh}} = 0\,, \tag{A.24}
$$

$$
\frac{\partial \mathcal{L}}{\partial t^A_{hh}} = -\nu^2 + \lambda_1 + \mu_1 \leqslant 0\,, \quad t^A_{hh}\frac{\partial \mathcal{L}}{\partial t^A_{hh}} = 0\,. \tag{A.25}
$$

From (A.24) we have $e^A_{hh} > 0$. Participation constraint (4.6) then implies that $t^A_{hh} > 0$ and it follows from (A.25) that $\lambda_1 + \mu_1 = \nu^2$. Thus $e^A_{hh} = 1$. By Assumption 2, $\Phi(e^A_{ll}) > 0$ and $\Phi(e^B_{ll}) > 0$, hence $t^A_{hh} > \frac{1}{2}(e^A_{hh})$ and, therefore, $\mu_1 = 0$ and $\lambda_1 = \nu^2$. Proceeding in a similar fashion, we find that $e^B_{hh} = 1$ and $\mu_5 = \nu^2$.

There are now four cases to consider, depending on whether or not acceptance constrains (4.3) and (4.4) are binding.

Case 1 ($\xi_1 = 0$**,** $\xi_2 = 0$)**: Full Collusion.**

The Kuhn-Tucker conditions for e_{hl}^A and t_{hl}^A are

$$\frac{\partial \mathcal{L}}{\partial e_{hl}^A} = \nu(1-\nu) - e_{hl}^A\,(\lambda_2 + \mu_2) \leqslant 0\,, \quad e_{hl}^A \frac{\partial \mathcal{L}}{\partial e_{hl}^A} = 0\,, \tag{A.26}$$

$$\frac{\partial \mathcal{L}}{\partial t_{hl}^A} = -\nu(1-\nu) + \lambda_2 + \mu_2 \leqslant 0\,, \quad t_{hl}^A \frac{\partial \mathcal{L}}{\partial t_{hl}^A} = 0\,. \tag{A.27}$$

Since $\xi_1 = 0$, we have $\Psi\big(e_{ll}^A\big) - (1+\delta)\psi\big(e_{ll}^B\big) > 0$ and $t_{hl}^A > \frac{1}{2}(e_{hl}^A)^2$, hence $\mu_2 = 0$. Then (A.26) and (A.27) imply that $\lambda_2 = \nu(1-\nu)$; thus $e_{hl}^A = 1$. In a similar fashion, we find that the agent's efforts in the *hh*- and *hl*-cases are given by:

$$e_{hh}^i = e_{hl}^i = e_{lh}^i = 1, \tag{A.28}$$

where $i = A, B$.

Next, substituting the values of λ_1–λ_3 and simplifying, we can write the Kuhn-Tucker conditions for e_{ll}^A and t_{ll}^A as:

$$\frac{\partial \mathcal{L}}{\partial e_{ll}^A} = (1-\nu)^2 - \nu\Delta\theta - e_{ll}^A\,(\mu_4 - \nu(2-\nu)) \leqslant 0\,, \quad e_{ll}^A \frac{\partial \mathcal{L}}{\partial e_{ll}^A} = 0\,, \tag{A.29}$$

$$\frac{\partial \mathcal{L}}{\partial t_{ll}^A} = -1 + \mu_4 \leqslant 0\,, \quad t_{ll}^A \frac{\partial \mathcal{L}}{\partial t_{ll}^A} = 0\,. \tag{A.30}$$

From (A.30) we have $\mu_4 = 1$. Also, it follows from Assumption 2 that $e_{ll}^A > 0$, hence, after simplification, we obtain from (A.29):

$$e_{ll}^A = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2}. \tag{A.31}$$

Finally, substituting the values of λ_1–λ_3 and simplifying, we can write the

Kuhn-Tucker conditions for e_{ll}^B and t_{ll}^B as follows:

$$\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = (1-\nu)^2 - e_{ll}^B \mu_8 - \Delta\theta\nu \frac{1-\alpha\big(2+\delta(2+\delta)(1-\nu)\big)}{(1-2\alpha)(1+\delta)} \leqslant 0, \tag{A.32}$$

$$e_{ll}^B \frac{\partial \mathcal{L}}{\partial e_{ll}^B} = 0, \tag{A.33}$$

$$\frac{\partial \mathcal{L}}{\partial t_{ll}^B} = -(1-\nu)^2 + \mu_8 \leqslant 0\,, \;\; t_{ll}^B \frac{\partial \mathcal{L}}{\partial t_{ll}^B} = 0. \tag{A.34}$$

From (A.34) if follows that $\mu_8 = (1-\nu)^2$, thus (A.32) can be written as

$$\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = (1-\nu)^2 \left(1 - e_{ll}^B\right) - \Delta\theta\nu \left\{1 - \delta\, \frac{1+\alpha\big(\delta(1-\nu)-2\nu\big)}{(1-2\alpha)(1+\delta)}\right\} \leqslant 0\,.$$

By Assumption 2, we have $e_{ll}^B > 0$, hence (A.33) implies that (A.32) holds with equality and the value of e_{ll}^B is given by

$$e_{ll}^B = 1 - \Delta\theta \frac{\nu}{(1-\nu)^2} \left\{1 - \delta\, \frac{1+\alpha\big(\delta(1-\nu)-2\nu\big)}{(1-2\alpha)(1+\delta)}\right\}. \tag{A.35}$$

Denote by α_1 the smaller of the two solutions to $\Psi\big(e_{ll}^A\big) - (1+\delta)\psi\big(e_{ll}^B\big) = 0$ and by α_2 the smaller of the two solutions to $\frac{1}{1+\delta}\Psi\left(e_{ll}^B\right) - \psi\left(e_{ll}^A\right)$, where the effort levels are given by (A.31) and (A.35). The Full Collusion (FC) region is then characterized by $\alpha \leqslant \alpha_0 \equiv \min\{\alpha_1,\, \alpha_2\}$.

Case 2 ($\xi_1 > 0$, $\xi_2 = 0$): Partial Collusion I.

We now have

$$\Psi\big(e_{ll}^A\big) - (1+\delta)\psi\big(e_{ll}^B\big) < 0,$$

where the effort levels are given by (A.31) and (A.35). That is, the employees do not collude when the supervisor is efficient and the agent is not, hence constraint (4.3) is now binding and constraint (4.1) can be rewritten as $t_{hl}^A - \frac{1}{2}\big(e_{hl}^A\big)^2 \geqslant 0$. Notice that in the PCI region constraint (4.4) is not binding. After simplification, the corresponding Kuhn-Tucker conditions for e_{ll}^A and e_{ll}^B take the following form:

$$\frac{\partial \mathcal{L}}{\partial e_{ll}^A} = (1-\nu)^2\left(1-e_{ll}^A\right) - \Delta\theta\nu\frac{\nu-\alpha(1+\nu)}{1-2\alpha} \leqslant 0,\ \ e_{ll}^A\frac{\partial \mathcal{L}}{\partial e_{ll}^A} = 0,$$
$$\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = (1-\nu)^2\left(1-e_{ll}^B\right) - \Delta\theta\nu\frac{1-\alpha(1+\nu)}{(1-2\alpha)(1+\delta)} \leqslant 0\,,\ \ e_{ll}^B\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = 0.$$

By Assumption 2, $e_{ll}^A > 0$ and $e_{ll}^B > 0$, hence the effort levels are given by

$$e_{ll}^A = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\,\frac{\nu-\alpha(1+\nu)}{1-2\alpha}, \tag{A.36}$$
$$e_{ll}^B = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2}\,\frac{1-\alpha(1+\nu)}{(1-2\alpha)(1+\delta)}, \tag{A.37}$$

Denote by α_3 the smaller of the two solutions to $\frac{1}{1+\delta}\Psi\left(e_{ll}^B\right) - \psi\left(e_{ll}^A\right) = 0$, where the effort levels are given by (A.36) and (A.37). The Partial Collusion I (PCI) region is then characterized by $\alpha_0 < \alpha \leqslant \alpha_3$.

Case 3 ($\xi_1 = 0$, $\xi_2 > 0$): Partial Collusion II.

In this region, constraint (4.3) is satisfied with equality but constraint (4.4) is binding: the employees collude in the *hl*-case only when the supervisor is efficient. Now, constraint (4.2) can be rewritten as the corresponding participation constraint: $t_{lh}^A \geqslant \frac{1}{2}\left(e_{lh}^A\right)^2$. We have the following Kuhn-Tucker conditions:

$$\frac{\partial \mathcal{L}}{\partial e_{ll}^A} = (1-\nu)^2\left(1-e_{ll}^A\right) - \Delta\theta\nu\frac{1-\alpha(1+\nu)}{1-2\alpha} \leqslant 0,\ \ e_{ll}^A\frac{\partial \mathcal{L}}{\partial e_{ll}^A} = 0,$$
$$\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = (1-\nu)^2\left(1-e_{ll}^B\right) - \Delta\theta\nu\left(\frac{\nu}{1+\delta} - \frac{\alpha(1+\delta)(1-\nu)}{1-2\alpha}\right) \leqslant 0\,,\ \ e_{ll}^B\frac{\partial \mathcal{L}}{\partial e_{ll}^B} = 0.$$

The optimal effort levels e_{ll}^A and e_{ll}^B are given by:

$$e_{ll}^A = 1 - \Delta\theta\,\frac{\nu}{(1-\nu)^2}\,\frac{1-\alpha(1+\nu)}{1-2\alpha}\,, \tag{A.38}$$
$$e_{ll}^B = 1 - \Delta\theta\,\frac{\nu}{(1-\nu)^2}\left(\frac{\nu}{1+\delta} - \frac{\alpha(1+\delta)(1-\nu)}{1-2\alpha}\right). \tag{A.39}$$

Denote by α_4 the smaller of the two solutions to $\Psi\big(e_{ll}^A\big) - (1+\delta)\psi\big(e_{ll}^B\big)$ where the effort levels are given by (A.38) and (A.39). The Partial Collusion II (PCII) region is characterized by $\alpha_0 < \alpha \leqslant \alpha_4$.

Case 4 ($\xi_1 > 0$, $\xi_2 > 0$): Partial Collusion III.

The Partial Collusion III (PCIII) region is characterized by $\alpha > \max\{\alpha_3, \alpha_4\}$. Now, both constraints (4.3) and (4.4) are satisfied with equality and, therefore, constraints (4.1) and (4.2) can be replaced by the corresponding individual rationality constraints. The optimal effort levels e_{ll}^A and e_{ll}^B are given by:

$$e_{ll}^A = 1 - \Delta\theta \, \frac{\nu^2}{(1-\nu)^2} \, ,$$
$$e_{ll}^B = 1 - \Delta\theta \, \frac{\nu^2}{(1-\nu)^2} \, \frac{1}{1+\delta} \, .$$

Since the objective function is (weakly) concave and the constraint set is convex, the Kuhn-Tucker conditions are sufficient as well as necessary.

Proof of Proposition 5

The full collusion region under both contracts is characterized by $\alpha \leqslant \min\big\{\alpha_{0_C}, \alpha_{0_D}\big\}$. The effort levels under contract D_1 are given by (A.28), (A.31), and (A.35). After substituting these values into the principal's objective function (4.8) and simplifying, we obtain:

$$\frac{\partial}{\partial \delta} \left(\Pi_{D_1} - \Pi_{C_1}\right)\bigg|_{\delta=0} = \frac{\Delta\theta\nu^2}{2(1-\nu)^2} \, \big\{(2-\Delta\theta)(1+\nu^2) - 4\nu\big\} \, .$$

By Assumption 2, we have $e_{ll}^A - \Delta\theta > 0$ (since $\alpha > \frac{1}{2}$), hence the following condition is satisfied with respect to $\Delta\theta$:

$$\Delta\theta < \frac{(1-\nu)^2}{1-\nu(1-\nu)}.$$

Thus we can write:

$$(2-\Delta\theta)(1+\nu^2)-4\nu > \frac{(1-\nu)^4}{1-\nu(1-\nu)} > 0,$$

which establishes the result. $\square$

Proof of Proposition 6

By the continuity of the principal's expected payoff in ν, for κ sufficiently close to 1 the same constraints will be binding in the full collusion region as in the solution to Problem D_1. Consider first the case where the principal appoints agent A to a supervisory position. Substituting the binding constraints in the objective function, we obtain:

$$\begin{aligned}
\Pi^A = {} & \kappa\nu^2 \Big(2\theta_h + e^A_{hh} - \tfrac{1}{2}\big(e^A_{hh}\big)^2 + e^B_{hh} - \tfrac{1}{2}\big(e^B_{hh}\big)^2 - \Phi\big(e^A_{ll}\big) - \tfrac{1}{1+\delta}\Phi\big(e^B_{ll}\big)\Big) \\
& + \nu\,(1-\kappa\nu)\Big(\theta_h + \theta_l + e^A_{hl} - \tfrac{1}{2}\big(e^A_{hl}\big)^2 + e^B_{hl} - \tfrac{1}{2}\big(e^B_{hl}\big)^2 - \big(\Psi\big(e^A_{ll}\big) - (1+\delta)\psi\big(e^B_{ll}\big)\big)\Big) \\
& + (1-\nu)\,\kappa\nu \Big(\theta_l + \theta_h + e^A_{lh} - \tfrac{1}{2}\big(e^A_{lh}\big)^2 + e^B_{lh} - \tfrac{1}{2}\big(e^B_{lh}\big)^2 - \Big(\tfrac{1}{1+\delta}\Psi\big(e^B_{ll}\big) - \psi\big(e^A_{ll}\big)\Big)\Big) \\
& + (1-\nu)(1-\kappa\nu)\Big(2\theta_l + e^A_{ll} - \tfrac{1}{2}\big(e^A_{ll}\big)^2 + e^B_{ll} - \tfrac{1}{2}\big(e^B_{ll}\big)^2\Big).
\end{aligned}$$

Maximizing Π^A above with respect to the effort levels yields:

$$e^i_{hh} = e^i_{hl} = e^i_{lh} = 1 = e_{fb}\,, \text{ where } i = A, B\,,$$

$$e^A_{ll} = 1 - \Delta\theta \frac{\nu}{(1-\nu)(1-\kappa\nu)} \, \frac{1-\alpha(1+\kappa)}{1-2\alpha}\,, \tag{A.40}$$

$$e^B_{ll} = 1 - \Delta\theta \frac{\nu}{(1-\nu)(1-\kappa\nu)} \, \frac{\kappa(1-\alpha) - \alpha\big(1+\delta(2+\delta)(1-\kappa\nu)\big)}{(1-2\alpha)(1+\delta)}\,. \tag{A.41}$$

Next, consider the case where the principal appoints agent B to the supervisory position. The maximization problem now takes the following form:

$$\begin{aligned}
\Pi^B = \kappa\nu^2 &\Big(2\theta_h + e_{hh}^A - \tfrac{1}{2}\big(e_{hh}^A\big)^2 + e_{hh}^B - \tfrac{1}{2}\big(e_{hh}^B\big)^2 - \tfrac{1}{1+\delta}\Phi\big(e_{ll}^A\big) - \Phi\big(e_{ll}^B\big)\Big) \\
&+ \nu(1-\kappa\nu)\Big(\theta_h + \theta_l + e_{hl}^A - \tfrac{1}{2}\big(e_{hl}^A\big)^2 + e_{hl}^B - \tfrac{1}{2}\big(e_{hl}^B\big)^2 - \Big(\tfrac{1}{1+\delta}\Psi\big(e_{ll}^A\big) - \psi\big(e_{ll}^B\big)\Big)\Big) \\
&+ (1-\nu)\kappa\nu\Big(\theta_l + \theta_h + e_{lh}^A - \tfrac{1}{2}\big(e_{lh}^A\big)^2 + e_{lh}^B - \tfrac{1}{2}\big(e_{lh}^B\big)^2 - \big(\Psi\big(e_{ll}^B\big) - (1+\delta)\psi\big(e_{ll}^A\big)\big)\Big) \\
&+ (1-\nu)(1-\kappa\nu)\Big(2\theta_l + e_{ll}^A - \tfrac{1}{2}\big(e_{ll}^A\big)^2 + e_{ll}^B - \tfrac{1}{2}\big(e_{ll}^B\big)^2\Big).
\end{aligned}$$

The effort levels are:

$$e_{hh}^i = e_{hl}^i = e_{lh}^i = 1 = e_{fb}\,, \text{ where } i = A, B\,,$$

$$e_{ll}^A = 1 - \Delta\theta\frac{\nu}{(1-\nu)(1-\kappa\nu)}\,\frac{1 + \alpha\big(\kappa\nu\delta(2+\delta) - 1\big) - \kappa\alpha(1+\delta)^2}{(1-2\alpha)(1+\delta)}\,, \tag{A.42}$$

$$e_{ll}^B = 1 - \Delta\theta\frac{\nu}{(1-\nu)(1-\kappa\nu)}\,\frac{\kappa - \alpha(1+\kappa)}{1-2\alpha}\,. \tag{A.43}$$

After substituting the effort levels given by (A.40)–(A.43) in the corresponding objective functions and simplifying, we obtain:

$$\begin{aligned}
\Pi^A - \Pi^B = &\frac{\Delta\theta\delta\nu(\kappa-1)}{2(1-2\alpha)^2(1+\delta)^2(1-\nu)(1-\kappa\nu)}\times \\
&\times\Big\{2(1-2\alpha)(1+\delta)\big(1-\alpha(2+\delta)\big)(1-\nu)(1-\kappa\nu) \\
&- \Delta\theta\Big[(1+\delta)\left(1-\big(2-\alpha(2+\delta)\big)\right) \\
&+ \nu(1+\kappa)\left(1-\alpha\left(2-\alpha(2+\delta)(1+\delta+\delta^2)\right)\right) \\
&+ \kappa\nu\left(1+\delta-\alpha\left(6+4\delta-\alpha(2+\delta)\big(1-\delta(3+2\delta)\big)\right)\right)\Big]\Big\}.
\end{aligned}$$

The sign of $\Pi^A - \Pi^B$ is determined by the sign of the expression in the curly brackets. For $\delta < \frac{1}{\alpha} - 2$, it will be positive provided that $\Delta\theta$ is not too high. Solving

$\Pi^A - \Pi^B = 0$ for $\Delta\theta$ yields:

$$\Delta\theta_1 = 2(1-2\alpha)(1+\delta)\big(1-\alpha(2+\delta)\big)(1-\nu)(1-\kappa\nu) \div$$
$$\div \bigg| \Big[(1+\delta)\left(1+\alpha\big(\alpha(2+\delta)-2\big)\right) + \nu(1+\kappa)\left(1+\alpha\big(\alpha(2+\delta)(1+\delta+\delta^2)-2\big)\right)$$
$$+ \nu^2\kappa\left(1+\delta-\alpha\left(6+4\delta+\alpha(2+\delta)\big(\delta(3+2\delta)-1\big)\right)\right)\Big]\bigg|.$$

Notice that $\Delta\theta_1$ is positive for $\delta < \frac{1}{\alpha} - 2$. $\square$

Proof of Proposition 7

The proof is structured as follows: I assume that the constraints specified in the text are binding, characterize the conditions under which the remaining constraints are slack, and compare the principal's payoff under the two contracts: D_2 and C_1 with $\delta = 0$, which I denote Π_{D_2} and Π_0, respectively. Diagrammatically, the binding incentive compatibility constrains are depicted in Figure A.1.

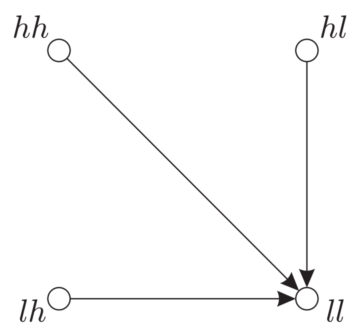

Figure A.1: The binding incentive compatibility constraints.

Substituting the values of U_{lh} and U_{ll} given by (4.14) and (4.15), which collectively constitute the $(lh \to ll)$ constraint, and the binding constraints given by (4.16) and (4.17) into the principal's objective function, we can solve for e^i_{jk}. The solution is given by (4.18) and (4.19).

Note, for future reference, that the optimal effort levels under the benchmark contract are given by

$$
\begin{aligned}
e^i_{hh} = e^i_{hl} = e^i_{lh} = 1 = e_{fb}\,,\ \text{where } i = A, B\,,\\
e^A_{ll} = e^B_{ll} = 1 - \Delta\theta\frac{\nu}{(1-\nu)^2} \equiv e_b\,.
\end{aligned}
$$

The full collusion region is then characterized by $\Psi\big(e_b\big) - \psi\big(e_b\big) \geqslant 0$, which holds for

$$
\Delta\theta \leqslant \Delta\theta^{\Psi}_b \equiv \frac{2(1-2\alpha)^2(1-\nu)^2}{1+\nu^2-2\alpha(1-\alpha)(1+\nu)^2}\,. \tag{A.44}
$$

In the remainder of the proof, I group the constraints to be checked by type.

Acceptance constraints. Substituting the effort levels given by (4.18) and (4.19) into the expressions for $\Psi(\cdot)$ and $\psi(\cdot)$ and simplifying yields:

$$
\Psi\big(e^B_{ll}\big) - \psi\big(e^A_{ll}\big) - \Big(\Psi\big(e^A_{ll}\big) - \psi\big(e^B_{ll}\big)\Big) = \frac{(\Delta\theta)^2\nu}{(1-2\alpha)^2(1-\nu)^2} > 0\,,
$$

hence the acceptance constraint is given by

$$
\begin{aligned}
\Psi\big(e^A_{ll}\big) - \psi\big(e^B_{ll}\big) = \frac{\Delta\theta}{2(1-2\alpha)^2(1-\nu^2)}\times\\
\times\left\{2(1-2\alpha)^2(1-\nu^2) - \Delta\theta\left(1-2\alpha(1-\alpha)(1+\nu^2)\right)\right\} \geqslant 0\,,
\end{aligned} \tag{A.45}
$$

which is satisfied for

$$
\Delta\theta \leqslant \Delta\theta^{\Psi} \equiv \frac{2(1-2\alpha)^2(1-\nu)^2}{(1-2\alpha(1-\alpha))\,(1+\nu^2)}\,. \tag{A.46}
$$

Participation constraints. By construction, the participation constraint for an inefficient supervisor, (4.11), is satisfied with equality. The participation constraint for an efficient supervisor can be written as follows:

$$
\nu\left(\Phi\left(e^A_{ll}\right) + \Phi\left(e^B_{ll}\right) - \left(\Psi\left(e^B_{ll}\right) - \psi\left(e^A_{ll}\right)\right)\right) + (1-\nu)\left(\Psi\left(e^A_{ll}\right) - \psi\left(e^B_{ll}\right)\right) \geqslant 0\,.
$$

It is satisfied if and only if the following condition holds:

$$\Delta\theta \leqslant \Delta\theta^P \equiv \frac{2(1-2\alpha)^2(1-\nu)^2}{1+\nu^2-2\alpha(1-\alpha)\big(1+\nu\big(2-\nu(3-2\nu)\big)\big)}\,.$$

It is easy to check that the denominator in the above expression is always positive. Furthermore, the following inequality holds: $\Delta\theta^\Psi - \Delta\theta^P < 0$. Indeed, the ratio

$$\frac{\Delta\theta^\Psi}{\Delta\theta^P} = \frac{1+\nu^2-2\alpha(1-\alpha)\big(1+\nu\big(2-\nu(3-2\nu)\big)\big)}{(1-2\alpha(1-\alpha))\,(1+\nu^2)}$$

is equal to 1 for $\nu = 0$ and

$$\frac{\partial}{\partial\alpha}\frac{\Delta\theta^\Psi}{\Delta\theta^P} = \frac{-4\nu(1-2\alpha)(1-\nu)^2}{(1-2\alpha(1-\alpha))^2\,(1+\nu^2)} < 0.$$

It follows that the participation constraint is implied by the acceptance constraint (A.45). As a consequence, the incentive compatibility of contract D_2 implies that the expected net transfer for an efficient supervisor is positive.

Incentive compatibility constraints. By assumption, in the *hh*-case it is more profitable for the supervisor to claim that the realization of parameters is *ll* than to claim that it is *lh*, i.e., the $(hh \to lh)$ constraint is not binding. This will be the case if the following condition holds:

$$\Phi\left(e_{ll}^A\right) + \Phi\left(e_{ll}^B\right) - \left(\Psi\left(e_{ll}^B\right) - \psi\left(e_{ll}^A\right)\right) - \left(\Psi\left(e_{lh}^A\right) - \psi\left(e_{lh}^B\right)\right) \geqslant 0\,,$$

which is equivalent to

$$\begin{aligned} &2\alpha(1-2\alpha)\,(1-\nu(1-\nu)) - \nu \geqslant 0 \;\Leftrightarrow \\ \Leftrightarrow &\nu \leqslant \nu_{ic1} \equiv \frac{1+2\alpha(1-\alpha)-\sqrt{1+4\alpha\big(1+\alpha\,(3\alpha(2-\alpha)-4)\big)}}{4\alpha(1-\alpha)}\,. \end{aligned} \tag{A.47}$$

Likewise, the supervisor in the *hl*-case should not benefit by, instead of claiming that the efficiency parameters are *ll*, claiming that the parameters are *lh* and enforcing the effort levels given by

$$\hat{e}^A = e^A_{lh} - \Delta\theta\frac{1}{1-2\alpha} \quad \text{and} \quad \hat{e}^B = e^B_{lh} + \Delta\theta\frac{1}{1-2\alpha}\,.$$

That is, the $(hl \to lh)$ constraint should be slack, which will be the case if the following condition is satisfied:

$$\Psi\left(e^A_{ll}\right) - \psi\left(e^B_{ll}\right) - \left(\Psi\left(e^B_{ll}\right) - \psi\left(e^A_{ll}\right) - c\big(e^A_{lh}\big) - c\big(e^A_{lh}\big) + c\big(\hat{e}^A\big) + c\big(\hat{e}^B\big)\right) \geqslant 0\,,$$

where I use the shorthand $c(e) = \frac{1}{2}(e)^2$ to save space. After simplification, we find that this constraint is equivalent to

$$\nu \leqslant \tfrac{1}{2}\left(3-\sqrt{5}\right). \tag{A.48}$$

Since $\nu_{ic1}|_{\alpha=\frac{1}{2}} = \frac{1}{2}\left(3-\sqrt{5}\right)$ and ν_{ic1} is increasing in α for $\alpha < \frac{1}{2}$, constraint (A.48) is implied by constraint (A.47).

Next, the supervisor in the hh-case should not benefit from claiming the hl-case. That is, the $(hh \to hl)$ constraint should be satisfied and the following expression should be nonnegative:

$$\begin{aligned}
&\Phi\left(e^A_{ll}\right) + \Phi\left(e^B_{ll}\right) - \Bigg\{\Psi\left(e^A_{ll}\right) - \psi\left(e^B_{ll}\right) - c\left(e^A_{hl} + \Delta\theta\frac{\alpha}{1-2\alpha}\right) \\
&\qquad - c\left(e^B_{hl} - \Delta\theta\frac{1-\alpha}{1-2\alpha}\right) + c\left(e^A_{hl}\right) + c\left(e^A_{hl}\right)\Bigg\} \\
&= \frac{(\Delta\theta)^2\alpha}{(1-2\alpha)^2(1-\nu)^2}\left[2 - \nu(3-2\nu) - 2\alpha\big(1-\nu(1-\nu)\big)\right].
\end{aligned}$$

It is easy to check that the expression in square brackets is always positive, hence the constraint, which I label $(hh \to hl)$, is slack.

Inverse incentive compatibility constraints. Since net transfers in ll- and hl-cases can be negative, the supervisor may benefit by claiming that either he, the agent, or both are more efficient than is the case. Therefore, I have to check the following inverse incentive compatibility constraints.

The $(ll \to lh)$ constraint is not binding if the supervisor does not benefit from claming the lh-state in the ll-state. This will be the case if the following expression is nonnegative:

$$
\begin{aligned}
&-\left(\Psi\left(e_{ll}^{A}\right)-\psi\left(e_{ll}^{B}\right)\right)-\left(\psi\left(e_{lh}^{A}-\Delta\theta\frac{\alpha}{1-2\alpha}\right)-\Psi\left(e_{lh}^{B}+\Delta\theta\frac{1-\alpha}{1-2\alpha}\right)\right)\\
&=\frac{(\Delta\theta)^2}{(1-2\alpha)^2(1-\nu)^2}\left[(1-\nu)^2-2\alpha(1-\alpha)\big(1-\nu(1-\nu)\big)\right].
\end{aligned}
$$

Substituting ν_{ic1} in the expression in the square brackets, it is easy to check that constraint $(ll \to lh)$ is implied by constraint (A.47).

The $(ll \to hl)$ constraint can be written as follows:

$$
\begin{aligned}
&\Psi\left(e_{ll}^{A}\right)-\psi\left(e_{ll}^{B}\right)-\left(\psi\left(e_{lh}^{A}+\Delta\theta\frac{1-\alpha}{1-2\alpha}\right)-\Psi\left(e_{lh}^{B}-\Delta\theta\frac{\alpha}{1-2\alpha}\right)\right)\\
&\qquad=\frac{\Delta\theta}{(1-2\alpha)^2(1-\nu)^2}\times\\
&\times\left[2+2(1-\alpha)\big(\alpha\nu(2+\Delta\theta)-4\alpha\big)-\nu(4+\Delta\theta)+2\nu^2(1-2\alpha)^2\right]\geqslant 0\,.
\end{aligned}
$$

Solving the expression in the square brackets for $\Delta\theta$, we can rewrite constraint $(ll \to hl)$ as follows:

$$
\Delta\theta \leqslant \Delta\theta_{ic} \equiv \frac{2(1-2\alpha)^2(1-\nu)^2}{\nu\left(1-2\alpha(1-\alpha)\right)}\,.
$$

Notice that

$$
\frac{\Delta\theta^{\Psi}}{\Delta\theta_{ic}}=\frac{\nu}{1+\nu^2}<\frac{1}{2}\,,
$$

hence the $(ll \to hl)$ constraint is implied by the acceptance constraint (A.45).

Next, consider the $(ll \to hh)$ constraint:

$$
\begin{aligned}
&\Phi\left(e_{ll}^{A}\right)+\Phi\left(e_{ll}^{B}\right)-\left(c\left(e_{hh}^{A}\right)+c\left(e_{hh}^{B}\right)-c\left(e_{hh}^{A}+\Delta\theta\right)-c\left(e_{hh}^{B}+\Delta\theta\right)\right)\\
&=\frac{\Delta\theta}{(1-\nu)^2}\left[4(1+\nu)^2-\nu(8+\Delta\theta)\right]\geqslant 0\,,
\end{aligned}
$$

which is equivalent to $\Delta\theta \leqslant \frac{4}{\nu}(1-\nu)^2$. Since

$$
\frac{\nu\Delta\theta^{\Psi}}{4(1-\nu)^2}=\frac{\nu(1-2\alpha)^2}{2\left(1-2\alpha(1-\alpha)\right)\left(1+\nu^2\right)}<\frac{1}{4}\,,
$$

the $(ll \to hh)$ constraint is again implied by the acceptance constraint (A.45)

Finally, the $(hl \to hh)$ constraint is written as:

$$\begin{aligned}
&\Psi\left(e_{ll}^{A}\right) - \psi\left(e_{ll}^{B}\right) - \Phi\left(e_{ll}^{A}\right) - \Phi\left(e_{ll}^{B}\right) \\
&\qquad - \left(\psi\left(e_{hh}^{B} - \Delta\theta\frac{\alpha}{1-2\alpha}\right) - \Psi\left(e_{lh}^{A} + \Delta\theta\frac{1-\alpha}{1-2\alpha}\right)\right) \\
&= \frac{(\Delta\theta)^2}{(1-2\alpha)^2(1-\nu)^2}\left[(1-2\alpha)^2(1+\nu^2) - 2\big(1-3\alpha(1-\alpha)\big)\right] \geqslant 0\,,
\end{aligned}$$

which is equivalent to

$$\nu \leqslant \nu_{ic2} \equiv \frac{1-3\alpha(1-\alpha) - \sqrt{\alpha(1-\alpha)\big(2-7\alpha(1-\alpha)\big)}}{(1-2\alpha)^2}\,. \tag{A.49}$$

To summarize, contract D_2 is incentive compatible if and only if the following conditions are satisfied:

$$\begin{aligned}
\Delta\theta &\leqslant \Delta\theta^{\Psi}, \\
\nu &\leqslant \min\left\{\nu_{ic_1},\, \nu_{ic2}\right\},
\end{aligned}$$

where the constraints are given by (A.46), (A.47), and (A.49), respectively.

Comparison with the benchmark contract. It follows from the characterization above that contract D_2 describes the full collusion setting. For the comparison between the two contracts, we thus have to confine our attention to the full collusion region of the benchmark contract, which is given by (A.44). It turns out that the acceptance constraint of contract D_2 always implies the acceptance constraint of the benchmark contract. To see this, observe that

$$\frac{\Delta\theta^{\Psi}}{\Delta\theta_b^{\Psi}} = 1 - \frac{4\nu\alpha(1-\alpha)}{(1-2\alpha(1-\alpha)(1+\nu^2))} < 1\,.$$

Substituting the values for corresponding effort levels in the objective functions and simpifying yields:

$$\Pi_{D_2} - \Pi_0 = \frac{\Delta\theta\nu}{2(1-2\alpha)^2(1-\nu)^2} \times \\ \left[2(1-2\alpha)^2(1-\nu)^2 + \Delta\theta\left(\left(1+2\alpha(1-\alpha)(1+\nu+\nu^2\right) - 2(1-\nu^2)\right)\right]. \tag{A.50}$$

Since the expression that is multiplied by $\Delta\theta$ in the square brackets is positive for $\nu \leqslant \frac{1}{2}\left(3-\sqrt{5}\right)$, constraint (A.47) implies that it is always positive. Solving for $\Delta\theta$, we find that (A.50) is nonnegative if and only if the following condition is satisfied:

$$\Delta\theta \leqslant \Delta\theta_\Pi \equiv \frac{2(1-2\alpha)^2(1-\nu)^2}{\left(1+2\alpha(1-\alpha)(1+\nu+\nu^2\right) - 2(1-\nu^2)}.$$

Next, observe that

$$\frac{\Delta\theta^\Psi}{\Delta\theta_\Pi} = 1 - \frac{\nu\left(1+2\alpha(1-\alpha)\right)}{\left(1-2\alpha(1-\alpha)\right)\left(1+\nu^2\right)} < 1\,,$$

hence the difference (A.50) is always positive if the acceptance constraint (A.46) is not binding. □

Proof of Corollary 2

After substitution and simplification, we obtain:

$$\frac{\partial}{\partial\alpha}\Pi_{D_2} = \nu\left(\Delta\theta\right)^2 \frac{1-\nu(1-\nu)(3-2\nu)}{(1-2\alpha)^3(1-\nu)^2} > 0,$$

which establishes the claim. □

Proof of Proposition 9

Solving the two versions of the principal's objective function, substituting the effort levels, and simplifying yields

$$\Pi^A_{D_2} - \Pi^B_{D_2} = \frac{\Delta\theta\nu(\kappa-1)}{2(1-2\alpha)^2(1-\nu)(1-\kappa\nu)} \times \\ \times \left[2(1-2\alpha)^2(1-\nu)(1-\kappa\nu) - \Delta\theta\left(1-2\alpha(1-\alpha)\right)\left(1+\kappa\nu^2\right)\right],$$

which is positive for

$$\Delta\theta < \frac{2(1-2\alpha)^2(1-\nu)(1-\kappa\nu)}{\left(1-2\alpha(1-\alpha)\right)\left(1+\kappa\nu^2\right)}$$

because, by assumption, $\kappa > 1$. $\square$

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